

A full-page background image featuring Batman in his iconic suit, riding a motorcycle down a city street at night. The scene is dramatically lit with warm, yellow streetlights and a large fire or explosion in the background, creating a sense of action and urgency. The motorcycle's headlight is on, and the large rear tire is prominent in the foreground.

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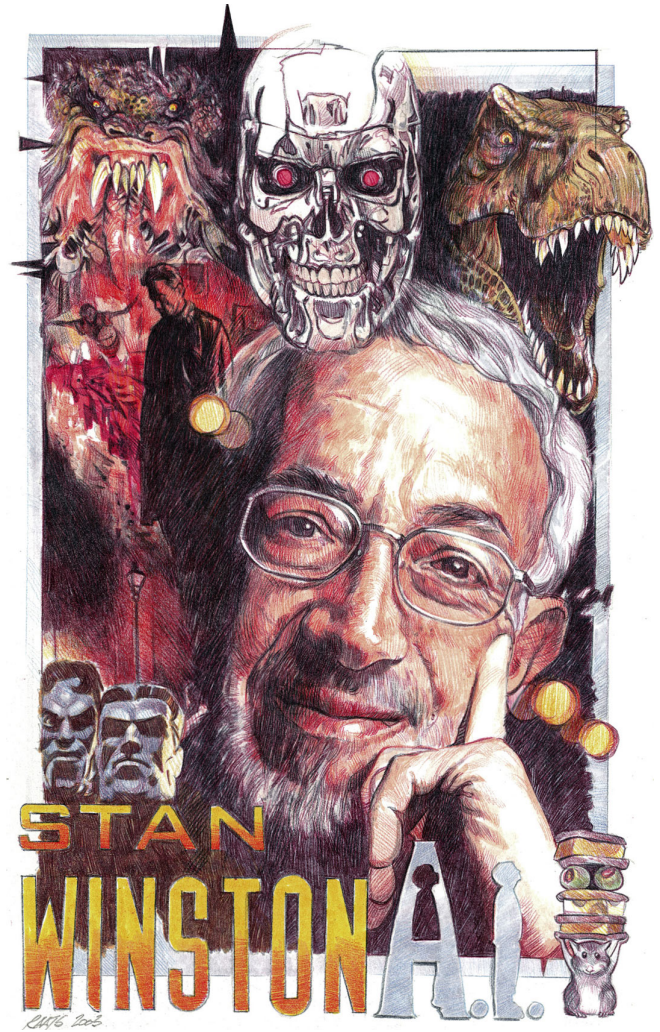
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Stan Winston

1946-2008

REMEMBRANCE BY JODY DUNCAN

Stan Winston first approached me about writing a history of his venerated Stan Winston Studio thirteen years ago. At that time, I'd known Stan for more than ten years, and I'd spent many hours with him, in his handsome office at the studio and on various movie sets. I'd become aware of him when we'd covered his work on *The Terminator* in the pages of *Cinefex*, and our professional relationship deepened two years later with our coverage of *Aliens*. I watched him in action many times on the set of *Terminator 2*, and I wrote about his work on that movie in a long *Cinefex* article and in a 'making of' book co-authored with Don Shay. *Cinefex* continued to follow Stan's rising star, a rapid ascension that culminated with his groundbreaking work on *Jurassic Park*, an achievement Don and I detailed both in the magazine and in another making of book.



About the time that the first Stan Winston Studio book project was proposed, I'd recently spent quite a bit of time with him on the set of *Congo*, preparing for yet another *Cinefex* article and book. (I recall watching him direct second unit on that film, trying to shoot his studio's gray gorillas — which looked beautiful and menacing in person — on a barren red clay set that featured no outcroppings, nooks, trees or foliage to provide dramatic lighting or cover.)

It was this long history of covering Stan's work that caused my name to come up as an author for the proposed Stan Winston Studio book. And so, I met with Stan and representatives from the publishing house that was involved at that time, and he took us all on a tour of his studio. I'd seen it before, of course — this tour was primarily for the publishing suits. (By the way, they were literally in suits, having come from the more formal New York publishing world. I chuckled to myself when Stan showed up for this meeting in a flannel shirt, jeans, down vest and hiking boots.) Stan was, as usual, very animated as he conducted what might otherwise have been a dog-and-pony show, but in this case was a T-Rex-and-Predator show. He exhibited tremendous pride in the many SWS characters on display, and he spoke with excitement about what it was that Stan Winston Studio did — which was not, he insisted, special effects. What Stan Winston Studio did was create characters.

Anyone familiar with Stan and his story knows that he'd first come to Hollywood hoping — and ultimately failing — to make it as an actor. Perhaps that's why it was so important to him that his work be thought of as character creation. He'd wanted to create characters using the tools of his body, his voice, and his imagination. Instead, he wound up creating characters through art and mechanics. That, more than anything else, was the message he wanted to convey to the little group on this studio tour.

"There," he said, pointing to the full-size Pumpkinhead on display, "what's that? That's a character!" He ran to one of the animatronic raptors from Jurassic Park. "And that! That's not a special effect. That's a character!" Pointing to the Predator — "And that? What is it? It's a character!"

It occurred to me as I watched him that there was no bigger character in the room than the man conducting the tour. A relatively slight man physically, Stan's smile was big, his gestures were big, his boasts and ambitions were big. He was a character all right — but not just in the way that people say, 'Wow, what a character.' I came to learn, as I got to know him better, that he was often an actor playing a role.

For example, he didn't mind playing the buffoon from time to time — breaking into a jig or putting his glasses cock-eyed on his head — if it made his crew members laugh and eased the tension on the set. But he was no buffoon. He was, in fact, a keen businessman; and it was that business acumen, as much as his talent, that had made his studio such a success.

He didn't mind playing the playful, excitable kid if it revved up his weary crew as they put in yet another long night in the shop. But he was no kid. He was, instead, a man with a very adult work ethic and discipline, a responsible father and husband.

He often played the mechanical and technological dunce. "I don't know how any of this stuff works," he'd say. But his mechanical designers contend that, even when he insisted otherwise, Stan 'got' what they were doing, entirely, and he was often the originator of innovative mechanical concepts.

On his tour for the prospective book publishers, he played the role of ringmaster, whipping up the small crowd's enthusiasm for the wonders in his many-ringed circus. That book project fell apart — and, in retrospect, it was a good thing that it did. Had I written the book then, it would not have included Stan's significant contributions to subsequent Jurassic Park and Terminator sequels, to Small Soldiers — in which the studio's high-tech toy soldiers starred — to Steven Spielberg's A.I.: Artificial Intelligence and the 34 other films that the studio worked on post-1995.

Fortunately, I got the opportunity to write a more definitive history of the studio ten years later, and that book became *The Winston Effect: The Art and History of Stan Winston Studio*. The last time I saw Stan was in his office just days after I'd received my advance copies. I'd asked him if he would sign one copy for me, and he said he would. After giving me a hug, he sat and thought a bit, and then he wrote a full-page note in silver pen. That note begins: "Dear Jody, this book signifies how blessed my career has been..."

Funny — that book signifies how blessed my career has been, too. It was a blessing to chronicle Stan's work. It was an honor to know him.

Q&A Eric Brevig

INTERVIEW BY JODY DUNCAN



Eric Brevig entered the visual effects field 27 years ago, when he served on the visual effects crew of Ridley Scott's *Blade Runner*. He joined Dream Quest Images in 1984, and moved up the ranks to become a visual effects supervisor there on *The Lost Boys* in 1987. The following year, Brevig worked with James Cameron on *The Abyss*, shooting underwater photography in his role as location visual effects supervisor. In 1990, Brevig won a Special Achievement Academy Award for his work on Paul Verhoeven's *Total Recall*. He then joined Industrial Light & Magic, where he continued as visual effects supervisor on a number of high-profile projects such as Steven Spielberg's *Hook*, Barry Sonnenfeld's *Men in Black* and *Men in Black II*, Michael Bay's *Pearl Harbor* — for which Brevig earned another Academy Award nomination — and Roland Emmerich's *The Day After Tomorrow*.



After 14 years at ILM, Brevig left to direct his first feature film, an updated take on Jules Verne's *Journey to the Center of the Earth*. Following the adventure that transpires when young Sean Anderson (Josh Hutcherson) and his Uncle Trevor (Brendan Fraser) travel to Iceland and explore the earth's very core in search of Sean's missing father, the stereoscopic film featured a number of exotic environments and otherworldly creatures, realized through visual effects that were artfully and budget-consciously conceived. Brevig discussed his debut film directing experience just as he was about to embark on a month-long promotional tour.

How did this directing project come about for you?

Through a producer friend of mine named Charlotte Huggins. When I was at ILM and she was still a visual effects producer, I'd worked with her on a 3D film for the Disney theme parks. She wanted to produce movies and I wanted to direct them; and so, intermittently over the next decade, we tried to find projects. *Journey to the Center of the Earth* was the first one that actually came to fruition.

How did that happen?

Charlotte called me late 2005, and said: 'I've been developing this 3D motion picture project with Walden Media, and we just lost the director we were working with. Can I send you the script?' So I read the script. At the time, I didn't think it was a very good story; but the idea was wonderful. I presented some of my ideas to the studio, and they liked them. Then we got financing from New Line, and we were off and running.

Had you been directing commercials prior to getting this movie?

No, but I'd directed second unit on the shows I'd done the effects for. They were all pretty big shows — Michael Bay and Barry Sonnenfeld movies — and so the second-unit work was extensive. In fact,

it was odd — when I walked on stage as the director of *Journey to the Center of the Earth*, I actually had a smaller crew than I was used to as the second unit director of these big Michael Bay movies! You said that you didn't like the story in the first script you read. How did the story evolve when you came on? What were the story ideas you pitched to the studio?

For one thing, the original script was a period story. It was basically Jules Verne's *Journey to the Center of the Earth*, which was written and set in the late 1800s. I didn't think that a period piece would be a very engaging setting for the movie. It would have been a slower movie, because, in those days, it would have taken six months just to get the characters to Iceland! I thought that by updating it, it would be a little more accessible to modern audiences. It would allow us to use some modern-day technology to keep the energy going and not dwell on all the difficulties one would have just traveling in those days.

So there was a complete rewrite of the script?

Oh, yeah, we rewrote the script two times before we went into production. Another big change was the relationship between the boy, Sean, and Brendan Fraser's character. Prior to my joining the show, that had evolved from a nephew/uncle story into a father and son story. But when Brendan came on the show, he said: 'I don't want to be a father who doesn't know his son well — that's a deadbeat dad. Let's go back and make it the uncle, because that's the way it is in the original story.' I agreed with that idea, and in the final rewrite we returned him to being Sean's uncle.

What other changes did you suggest when you came on the project?

The original plan had been to shoot nearly all the live-action bluescreen, and then surround the actors with CG environments, *Sky Captain*-like. That was the preferred approach of the director who preceded me. But I didn't think that was the best approach — not for the photorealistic quality I wanted in the film. Also, having worked with actors on bluescreen stages for a long time, I thought I would get much better performances if I had some set pieces for them to interact with, physically. I thought the movie, overall, would look a lot better. So that was the approach we took. We shot most of the movie on stage at a studio in Montreal.



*After distinguishing himself in the visual effects field for nearly three decades — working with A-list directors such as James Cameron, Steven Spielberg and Michael Bay, and winning a Special Achievement Academy Award for his work on *Total Recall* — visual effects supervisor Eric Brevig brought his considerable filmmaking experience to bear on his first directing project, *Journey to the Center of the Earth*. A modern take on the classic Jules Verne novel, the stereoscopic film follows young Sean Anderson (Josh Hutcherson) and his Uncle Trevor (Brendan Fraser) into an exotic world within the earth's core. Brevig confers with Fraser on the set.*

A chunk of the film is set in Iceland. Did you do any location shooting there?

Just two days. We really scrambled. We shot the aerials on one day and the coverage of the actors on another. Virtually everything else was shot on stage. We did shoot a couple of local locations in Montreal, which just barely masqueraded as Iceland. The shack where Hannah lives and the Italian man's vineyard you see at the end of the movie — those were only about 100 feet apart in a public park in Montreal. We were just careful with camera angles so we didn't see the city or the people watching.

Let's get into the stereoscopic aspect of this. This movie was always going to be 3D, from the beginning?

Yes. Walden Media had produced the two Jim Cameron underwater documentaries, *Aliens of the Deep* and *Ghosts of the Abyss*, which was 3D; and so, they were trendsetters in that area. I think they were just open to it and weren't afraid of it, because they'd done this 3D documentary.

What was your previous experience with stereo moviemaking? You mentioned work ten years ago or so on a Disney theme park 3D film.

There was that. Also, prior to this project coming together, I was the effects supervisor doing proof-of-concept work on *Avatar* for Jim Cameron. So I had a chance to evaluate the 3D system he was developing for that movie and compare it to other 3D camera systems. Jim became a supporter — not only of me as a friend who was now making the move to directing, but also as a guy who would take his equipment and actually try it out on a feature before he got going on *Avatar*.

Would you describe that system? What are its components?

It's actually a camera rig that houses two Sony F-950s, one for the left eye, one for the right eye. F-950s are unique in that the lenses and the sensors are removable from the rest of the camera electronics. So what is housed in a little device on the set is literally just two lenses and two sensors — everything else is up to 400 feet away, linked to the set via fiber optics. So they don't have more of a presence on the stage than a normal-sized camera.



Exploring a geological site in Iceland, Sean, Trevor and mountain guide Hannah (Anita Briem) take a long fall that lands them at the center of the earth. For a wide reveal, Hybride created a synthetic environment to extend a stage cave set. Hybride artists tweaked interocular distances between virtual cameras, repositioned actors, and added midground rock formations and flying 'glow' birds to suggest depth and scale in the final stereoscopic image. Hybride and the show's other effects vendors worked under visual effects supervisor Christopher Townsend.

So it doesn't affect your camera mobility?

No. Initially, when I tested the system, the smallest rig that they had was too big for me to use. It was a customized rig that used a beam-splitter so the two cameras could see straight ahead but they weren't physically next to each other. That configuration enables you to reduce the distance between the two lenses so that they are closer than you could physically position them in a side-by-side rig. That's a common approach to 3D photography, which has been around for many years. But, because a lot of this film was going to involve handheld camera work in a tight cave environment, I needed something smaller that could go on a Steadicam or be handheld. And, after they saw a test I shot with their big cameras, they appreciated how useful it would be to have a smaller version. So they built that rig, literally finishing it a week before we started shooting! Since we didn't have any time to test it, my first two days' dailies were the alpha tests. Luckily for me, it worked. They called it the 'mini studio rig' or something like that, and that became my primary choice for photography.

This is the first 3D movie I've ever seen where I didn't have a headache afterwards. Is that because the technology is better, or did it have something to do with the way you shot it?

Both. First of all, before we even started shooting I studied what it was that causes eyestrain in 3D movies. There are photographic and projection aspects to it. You get eyestrain when the alignment of the images isn't good, when one eye sees something in the wrong place from where it should see it. If it is higher or lower than what the other eye is seeing, or if it is too far to the right or left of what your other eye is seeing, you become wall-eyed or cross-eyed. Luckily, with a digital projector, the projection part of it is completely controllable. You've got a single projector, so the images hit the screen exactly as you photographed them, right-eye, left-eye. That takes one major difficulty out of the process.

What's the photographic component?

In a lot of 3D photography, you are whipping the audience's eyes from way behind the screen, to way in front of the screen, back and forth. You are asking the audience to focus their eyes on the movie screen — which they have to do to watch the movie — and yet converge their eyes way out in front of the screen, or way behind it. When you do that, it tires out your eyes and is uncomfortable, especially in something as long as a feature-length movie. So I came up with two main rules of photography, one of which was that I would always keep the focus of the shot — not the ocular focus but the focus of attention, where the audience was looking — near the screen plane. Unless I was doing a big 3D moment with something flying out at you, the subject matter that you would normally be watching in the film — usually the actors' faces — would be photographed so that they would appear near the plane of the movie screen, which is the most comfortable place for viewers.



Hybride created a reverseangle shot, which illustrated the vastness of the earth core environment while also providing for a dramatic stereoscopic moment as the glow birds flew toward camera. To facilitate handheld shots within a confined cave set, Brevig shot the 3D film with a much smaller version of a state-of-the-art stereoscopic camera rig developed for James Cameron's Avatar.

What was the second rule?

The second rule was that by adjusting the distance between the two lenses, I would always compress the volume of depth to whatever level was within a comfortable viewing range. In 3D photography, you can shoot a closeup of someone, and the background will be so far beyond infinity that you have to go wall-eyed to look at it. That problem goes away if you bring the lenses closer together. The things furthest away come closer and closer, until they are at normal infinity, which is much more comfortable to view.

I assume this was a pretty small-budget movie, and yet there is a lot of effects value on the screen. How did you make the most of your effects budget?

Having done visual effects for so many years, I knew how to design a sequence, and stage it and shoot it so that I could maximize the effects expenditures. I could look at a shot and know that if I put the camera two feet to the left of where it would normally go, I would save \$50,000 and not have to do six extra steps. It's the kind of thing that as an effects supervisor you are often whispering to the director on set — and usually he doesn't want to hear it. In my case, I was easy to convince! I knew that I could get 40 percent more exciting movie product on the screen if I was a bit conservative in how I spent my money; and I always evaluated every effects shot in terms of bang for the buck. That's why some shots are only minimally fleshed out in some areas. If you know where the audience is looking and what they're paying attention to, you can get away with a lot.

It's the old magician's trick. You ensure the audience is looking at your left hand while your right hand is making the switch.

That's exactly the analogy I've used. Where is everybody looking? They are looking over here — so don't worry about the lack of matte painting detail on the other side of the screen.

Talk to me about your effects team. What effects vendors did you use, and why did you choose them?

Chris Townsend was my visual effects supervisor, and he was in charge of working with the visual effects houses in Montreal — Hybride, Meteor Studios, Frantic Films, Rodeo FX, Mokko Studio. We divided up the work in a way that played to everybody's strengths.



Among the environments Sean, Hannah and Trevor encounter as they explore the center of the earth is a giant mushroom grove, established in a shot created by Hybride. When a first attempt at the synthetic environment looked too much like a multiplane miniature, Hybride artists varied the focal lengths and the interocular distances between virtual camera lenses, and added a dolly and tracking camera to achieve the volume, depth and scale that Eric Brevig was after. Dramatic lighting and atmospheric haze brought the shot to completion.

Did you work with any effects vendors here in the U.S.? Or were they all in Montreal?

Because of financial limitations and the tax laws, the studio told us that we couldn't do anything outside of that province. So basically anybody with a computer and some visual effects knowledge in Montreal was hired to work on the film. Chris' job was to help them if they were working in areas they hadn't before, to elevate their game and give me what I needed.

What was the final visual effects shot count?

We did 750 unique shots; but then, having to render a right eye and a left eye for every one of those shots brought us to 1,500.

Let's talk about some of the standout effects, such as the computer animated 'electric birds' that appear throughout the movie.

We called them 'glow birds,' and there's a frustrating story that goes along with them. Late in postproduction, the studio decided the birds shouldn't be glowing. I said, 'I guarantee that the sequence will work wonderfully when they are glowing' — but there was some concern about the look of it, and I lost that battle. They told the effects house to take off the glow, and the effects house followed their orders. But I wouldn't give up, and finally I said to them: 'I think this is a big mistake; and so, if you won't give me any money to do it, I'm going to get the alpha mattes from the effects house, and I'm going to do the glows myself on my laptop, in Shake. I'll make a separate series of shots and show you how good it looks.' I was so sure that the movie needed this, I was determined to do it myself if that was the only way to get it done.

Did you actually do that?

I did, and I expected it to be a blast, but it wasn't. I wound up putting those stupid glows back on the birds for hours, everywhere — literally, wherever I was going, whatever I was doing, whenever I was on an airplane or at home or at my office, I was putting glows on these birds.

So let me get this straight: As a director, you wound up doing hands-on work you probably haven't had to do as a visual effects supervisor for twenty years.

It's true. Probably the last time I did anything like that was on a down-shooter in the chemical days. I had Shake, but every step of the way I had to look up how to use it, because I'd never hands-on used the damn thing! I enjoyed figuring out how to do this on the first two shots — but the other 35 were really grueling. On the positive side, it gave me very good insight into how to help the people who were doing the other shots, how to deal with right eye and left eye issues, because I certainly uncovered every possible mistake you could make as I was doing it.



Separated from Hannah and Trevor, Sean wanders into a dinosaur graveyard strewn with skeletal remains. Meteor Studios created the virtual environment to tie in with a stage set realized by production designer David Sandefur. Meteor's set extension included jagged CG rocks meant to lead the audience's eyes back in stereo space to a fissure on the cliff face in the distance.

What were the most challenging effects shots, given the constraints of budget and the special problems of stereoscopic filmmaking?

The most challenging, I think, were the ocean shots, with the fish and the sea creatures interacting with the water. Everything becomes more difficult when you have to do it in stereo. All the cheats that we like to do, like using splash elements and fire elements and things like that, don't work because you can see that they are little flat elements on cards. So things that are not that difficult in a 2D movie become challenging in stereo. Water, which is pretty challenging even in a 2D movie, becomes a real mine field of problems, because high-quality simulated water is made up of layers and layers of different particles. Invariably, some of those elements would find their own place in Z-space, other than where they were supposed to be in the composite. We were constantly looking at shots, and saying, 'Hmm, something is flying around here — oh, that's a whitecap element that should be in the distant background, but has been imaged in space in front of the boy's shoulder for some reason.' We always had to track those things and get them back in line.

So it was like wrangling cats.

Exactly. The interaction of the creatures — the fish and the plesiosaurs, which were the sea monsters — with the water was also a nightmare because we had renders from different types of 3D models that had to work together. But I was very pleased with that interaction.

What's next for you?

If audiences come to see this movie I intend to keep directing. I had a great experience. It was a chance to do all the stuff that I normally did as an effects supe, except I didn't have to convince the director to do it my way! And there was also the creative satisfaction of sorting out story and character with the actors — all of that was very enjoyable. So I hope I'll be able to do it again. I've been receiving a lot of scripts from producers who have seen the movie in advance, so it is looking very promising.



Trevor runs from a gigantosaurus, a Meteor Studios computer animated creature. Originally conceived as an albino dinosaur, the all-white beast resembled an unpainted computer model when it was integrated into the environment, leading Meteor Studios to add skin color and textural details such as scars, gashes and dirt. To suggest the running creature's interaction with the environment, Meteor integrated CG particle passes into the shot, which afforded more control over the stereoscopic space than would have been possible with photographic dust elements.

Journey to the Center of the Earth photographs copyright © 2008 by Walden Media and New Line Cinema. All rights reserved. Special thanks to Chris Townsend and Gillian Smith.

Overview

Carey Villegas & Ken Hahn on Hancock

Article by Joe Fordham

Movie superheroes of all shapes and sizes have been populating multiplexes in great profusion of late. The most atypical among them is Hancock, a flying, supernaturally strong superhero with issues that include amnesia, alcoholism and a very bad attitude about his gig as lone crusader. In Hancock, boxoffice champion Will Smith plays the fallen-from-grace crime-fighter, who receives an image makeover in the hands of a sweet-natured public relations man, Ray Embrey (Jason Bateman).



Visual effects designer John Dykstra — whose personal superhero lineage included two Batman films and the first two Spider-Man movies — led the effects initiative on Hancock, accompanied by special effects supervisor John Frazier, Sony Pictures Imageworks and a battery of additional vendors that included Luma Pictures, X1FX, Yannix Technologies, Furious FX and Eden FX.

Imageworks digital effects supervisor Ken Hahn accompanied Dykstra on the shoot, and then joined forces with Imageworks' visual effects supervisor Carey Villegas in postproduction to realize director Peter Berg's idiosyncratic vision. "Peter Berg's previous films, *The Kingdom* and *Friday Night Lights*, had very unique styles of photography," observed Villegas. "Camera moves were fast and frenetic, with lots of long-lens shots, zooms and rack focuses. Hancock was similar, which made the visual effects work that much more difficult; but we were determined to match that style."

Working from production animatics, Dykstra and Imageworks designed visual effects shots that were a deliberate departure from the graceful, dynamic shooting style of previous superhero movies. "We wanted it to feel like Hancock was operating with too much alcohol in his system," explained Ken Hahn. "He was often staggering as he walked along, or his eyes couldn't focus. Our animation supervisor, Peter Giliberti, tried to keep flying scenes somewhat kinetic, but not kinetic smooth like we had on Spider-Man. It was more like the very first Spider-Man, when Peter Parker was just trying to discover his powers. There were always errors in the way he operated."

Hancock is first seen awakening from inebriated slumber on a concrete street bench, and then blasting skyward. Smith mimed the beginning of his takeoff on location in downtown Los Angeles, where John Frazier's team rigged the concrete bench to explode as a practical effect. Imageworks then animated Hancock's flight as a blur of speed moving erratically through the sky. "A lot of our

flying shots were bookended by stunt shots and practical effects,” said Carey Villegas. “We tried to carry the style of that photography into our flying shots, keeping camera moves very erratic.”

For Hancock’s grander entrances and exits, stunt coordinator Simon Crane flew the actor over streets using wire rigs. “I was surprised by what Will Smith did in person,” commented Ken Hahn. “He’s probably one of the top three movie stars working today, and we were hanging him on a crane 70 feet in the air. They took all the appropriate safety measures, going through a full day of prepping each effect and using computer controlled winches; but it was a lot of trust to place on a four-point wire harness. Will stayed in character the whole time, without showing any fear? at all.”

Hancock’s takeoffs and landings, as well as his unusual crime-fighting tactics, frequently accrue considerable collateral damage, such as blasting holes in city streets. The art department simulated the damage as set dressing; then Imageworks enhanced it digitally. “Our effects lead, Stephen Marshall, did most of the cratering effects as rigid body dynamics simulations in Side Effects Houdini,” said Hahn. “When we applied correct physics to the simulations, we found it usually wasn’t enough to sell the power of what Hancock was doing; and so we added more passes. We first fractured larger, solid chunks. Then we added smaller pieces, and kept refining that down to dust cloud effects. We generated textures mixing plate projection onto geometry, paint work and RenderMan shaders.”

To create Will Smith’s digital double, Imageworks started with a Gentle Giant cyberscan of the actor, and then employed facial motion capture — as used on Beowulf and Superman Returns — and image-based lighting surveys created at University of Southern California’s Institute for Creative Technologies Light Stage. “We knew we were going to have shots that transitioned from CG to live-action Will Smith, and vice versa,” commented Hahn. “Will is such a recognizable person, we had to create a very believable likeness.” John Dykstra directed facial capture sessions in postproduction with Imageworks motion capture supervisor Demian Gordon, using reference of edited film footage to help guide facial performances to specific scenes.

Hancock’s informal and varied attire required extensive digital cloth simulations. “It might not have been obvious to the casual viewer,” remarked Hahn, “but in each new sequence Hancock was dressed a little differently — a different pair of shorts, a different shirt or a different hoodie. This meant our digital double required multiple cloth builds, each with slightly different properties.”

After introducing the character in a chaotic freeway chase, the story takes a pivotal turn at a railroad crossing, where Hancock steps in front of a speeding freight train to flip Ray Embrey’s stalled car out of the engine’s path. The production shot the scene on location in Long Beach, using mechanical effects to simulate Hancock’s lifting abilities, and a full-scale locomotive fitted with a crumpled front extension to simulate after-effects of a collision with the superhero.



When the sequence was selected for early teaser trailer delivery, John Dykstra and New Deal Studios shot a 1/4-scale miniature of the train wreck.

Imageworks then integrated miniature elements with digital effects, and continued to finesse the shots for the finished film. “We wound up using parts of the miniature in the final shot,” explained Hahn, “but we knew that we’d be racing against the clock for the trailer, so we worked on it in parallel with the miniature shoot, trying to see how far we could take it digitally within the time frame. The trailer contained more miniature; in the final version, we salvaged about a quarter of that and the rest was digital, incorporating Peter’s requests and changes.”

Hancock distinguished itself among the crop of summer superhero movies with boxoffice megastar Will Smith occupying the title role of a crimefighting vigilante possessing as many personality defects as superpowers. Reprising the roles they had played on the Spider-Man films, visual effects designer John Dykstra, special effects supervisor John Frazier and the team at Sony Pictures Imageworks brought to life director Peter Berg's vision of the offbeat hero's rough and tumble world. Imageworks digital effects supervisor Ken Hahn accompanied Dykstra on the shoot, and in postproduction joined forces with Imageworks visual effects supervisor Carey Villegas and a battery of additional vendors.



Hancock attempts to reshape his tarnished image by donning a superhero costume and assisting the Los Angeles Police Department during a bank heist shootout. John Frazier's team furnished pyrotechnics and an exploding sports utility vehicle on location in downtown Los Angeles. The visual effects team then photographed Will Smith against an adjacent greenscreen to duplicate the lighting conditions. Imageworks composited Smith into the plate and used a digital double of Hancock matchanimated to the actor to create interactions of the character passing through smoke and a hail of bullets.

For a view from the train's footplate, Imageworks digitally generated Embrey's car as Hancock maneuvered the vehicle aside. Smith performed his reaction to the beginning of the train's impact. Imageworks CG supervisor Robert Winter then transitioned to a CG Hancock and wrapped the front of a digital locomotive around the figure, combined with parts of the miniature cowcatcher. Animators reverse-engineered twisting metal to match the physical set piece of the wrecked train. For the sequence's coda, Imageworks added a digital matte painting of the Los Angeles skyline and revealed the full impact of the derailment. "We got to art-direct that shot quite a bit," observed Carey Villegas. "As the camera craned up from a low angle to reveal the damage, we choreographed the shot so the viewer's eye went from the foreground all the way back. We digitally removed the carriage behind the engine, then added movement to other cars as train parts stacked on top of each other and came off the rails in a domino effect."

Embrey later reviews Internet video clips of Hancock's previous inebriated rescue missions, including a misguided attempt to save a beached whale. On location in Malibu, production shot the whale rescue with Smith interacting with a full-scale dummy representing the front quadrant and flipper of 'Walter' the gray whale. Performers grappled with the prop in closeups; but for wide shots, Imageworks removed the prop entirely and animated a CG whale, sand and water interactions, and a passing sailboat, which Hancock inadvertently flattens by hurling Walter out to sea.

Thrown in jail, Hancock makes good on a sardonic threat aimed at two aggressive inmates. Peter Berg staged the ghastly outcome of the scene by positioning the inmate performers so that one's head appeared to be rammed up the other's rear end. Unsatisfied with the in-camera effect, Berg enlisted Imageworks to hammer home the gag. "Pete bluntly wanted to show it," said Ken Hahn. "We had never planned this as a visual effect. We had no data acquisition, lighting reference, or camera information; but Pete gave us a rah-rah speech about how it would be a hilarious shot. I gathered CG supervisor Thomas Hollier and our lead artists, showed them the shot and described what was required. There was a hushed silence, and then they said, 'Let's do it!'"

Imageworks created the illusion by rebuilding portions of the actors. "We erased the lower half and arm of the taller actor," Hahn explained, "because the performance didn't match what we were doing digitally. We digitally re-created his lower half and arm, and the person who had his head in



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the unfortunate place was a complete digital replication. We had no reference apart from shots of the actors earlier in the scene, so we just kept working on the modeling, physiquing of the rigs, cloth simulations, lighting and compositing until we made them match.”

Bent on reforming his destructive ways, Hancock returns to civilian life to lend assistance to Los Angeles police officers during a bank robbery gunfight downtown. The production filmed Hancock flying into the scene using a wire rig on location. “The mechanical rig worked well in the context of the scene,” Hahn observed. “It was somewhat awkward for Hancock to land gracefully, as opposed to his usual freefall; but he was trying to act the part and maintain his posture as he came in for the landing. So Will landed gingerly on the wire rig as he met the police chief. We transitioned into that from our CG character, trying to keep his landing not entirely smooth.” John Frazier’s team also provided a mechanical rig as Hancock rescues a trapped police officer using a bullet-riddled cop car as a shield. “They had a big rod that came out the back of the car; and a couple of cables helped suspend it in the air as Will pretended to carry it along. The destruction of the car was a mix of digital and practical effects. The big pieces that fell off — the hood, emergency lights and doors — were practical. All the sparks, bullet tracers and smaller debris were digital.”

The film reaches its finale in a battle between Hancock and Ray’s wife, Mary (Charlize Theron), who reveals her own superhero abilities in a duel on Hollywood Boulevard. For the sequence, shot on location in Hollywood over the course of a week, the production cordoned off streets and trucked in debris to represent broken road surfaces. Dykstra and an Imageworks crew then photographed Vistavision background plates and re-created the environment digitally by tiling plates together, combined with animation of the destruction and atmospheric phenomena augmenting physical effects.



Hancock stops a freight train from crashing into a car stalled on a railroad crossing, but miscalculates his powers, causing a disastrous derailment. The production filmed the scene on location in Long Beach, California, using a full-scale locomotive fitted with a crumpled front extension to simulate after-effects of a collision with the superhero. Imageworks enhanced the collision with a New Deal Studios miniature element and digital effects, choreographing CG railcars piling off the track. Imageworks artists then tracked elements into the slowly rising crane shot, adding atmospheric effects and the downtown Los Angeles skyline.

John Frazier's team supplied rigs to simulate Mary lifting the front tires of a cement truck off the street, and then the production provided set dressing of the shattered truck and street. Imageworks animated Mary wielding the truck, trying to swat Hancock, and choreographed storm clouds conjured by Mary's god-like wrath and tornadoes that Hancock summons in response. "We had a very limited time on location," noted Carey Villegas. "We had to shoot in whatever lighting conditions we could get; then we transitioned from the high-contrast sunlit plates into the storm by doing a digital intermediate before we started integrating elements. We then played a creative role in art-directing the movement of the tornadoes and cloud simulations."



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Imageworks drew on its experience with complex particle animation to generate snow, lightning and dust storms that rage through the scene. As the fight migrates to a neighboring construction site, shots combined bluescreen closeups of actors with digital backgrounds, and digital stunt doubles in all-digital environments populated with volumetric weather



effects. “Vincent Serritella was our lead effects person on elemental effects,” said Ken Hahn. “He worked with senior technical director Magnus Wrenninge, who had previously developed the volume renderer for Sandman in Spider-Man 3. The clouds were simple sphere primitives rendered through our proprietary volume renderer. The tornadoes were physical simulations animated mostly through control curves. We built the volumes and populated them with our volume renderer, then took vector fields from the simulations and applied secondary effects of swirling dust and debris.”

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The confrontation leads Hancock to a tragic realization of his own mortality, which he tests by leaping from a 10th-floor hospital window. Imageworks digital doubles intercut stunts and practical wire-flown shots throughout the sequence. “The interior shot where Hancock jumps out of the window was a stunt shot on stage in front of greenscreen,” explained Hahn. “We broke the glass out digitally and added the exterior environment behind that. The reverse shot outside the window, with Hancock jumping out in slow motion, we designed in the 11th hour and 59th minute, within just a couple of weeks of the release. Our guys just rolled with it and created a shot that you do not even question as real when you see it in the film. Then we used our digital stunt double for an exterior at ground level where Hancock bounces off two buses. As he runs and tries to regain his strength to fly away, they had a stunt performer on a wire rig and we did digital head replacements. But Will performed several shots hanging from a huge crane rig that ran him down the street at maybe 40 miles an hour.”

The movie concludes with an epilogue depicting Hancock in New York City, where he leaps from the top of the Empire State Building and flies off into the night. The epic shot was a return to familiar territory for Imageworks, which utilized digital city-building technology honed over nearly a decade of superhero films. “This type of shot has become second nature for us now,” commented Hahn. “It was a mix of digital tiles, 2½D matte painting and our very familiar digital 3D tools. The tricky thing about the shot was it started with Will and a live eagle at the top of the building shot on a bluescreen stage. We then did a 360-degree move around him as he dove off the building. We had to hook that element into our digital character, so we were locked into those camera moves. We wanted to retain the live-action performance because we got a very good look at Will, and Pete had directed him to perform a very specific action. We transitioned to our CG Hancock when the camera got behind him, then he swung around a corner, flew over some flagpoles and flew off down the street.” The final composite included greenscreen elements of Imageworks employees populating the street and fleets of cars and taxicabs, until the camera pulled back to a vista of the city.

After editorial changes, the final cut of Hancock ran only 92 minutes, but included 525 visual effects shots out of more than 650 created for the movie. "There will be a lot of deleted scenes to choose from as DVD extras," commented Carey Villegas.

Despite its gritty style and unusual take on the genre, Hancock's demands and visual effects challenges were typical of those for any modern superhero film. "In every movie that I have worked on there have always been shots that come up that you don't plan for," concluded Ken Hahn. "This certainly happened to us on this one. And the shots still took one or two hours per frame to render. That hasn't changed in the 12 years that I have been at Imageworks! It seems the amount of information being crammed into shots just keeps growing. And I don't foresee that metric ever changing that much.

We could get faster as we build more computer memory, or as artists become more skilled, but it always takes time to get shots out of the door because filmmakers are always asking for much more. Any time I start to think we've reached the limit of what can be done, there is always someone with imagination who is going to ask for something new. So, we scratch our heads and try to figure it out until we end up saying, 'Wow, that looks great!'"

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In a climactic duel, Hancock battles a super rival on Hollywood Boulevard and summons tornadoes to counter a powerful storm summoned by his opponent. The production filmed the sequence on location in Hollywood, cordoning off streets and dressing debris on the roads. John Dykstra and Imageworks shot Vistavision plates and surveyed the area, then digitally reconstructed the environment. Imageworks created atmospheric phenomena by drawing on its experience with complex particle animation used on Spider-Man 3 to generate volumetric weather effects and lightning.

Paranormal Parade

ARTICLE BY DAVID W. MARSHALL

In 2004, director Guillermo Del Toro introduced moviegoers to a kitten-loving, rough-around-the-edges hero well known to comic book readers. Hellboy (Ron Perlman), the red demon with a big stone hand and ground-down horns, battled a reborn Rasputin and his Nazi followers to defend the world from Hell on earth. With a pyrokinetic love-interest, Liz Sherman (Selma Blair), an amphibious telepath, Abe Sapien (Doug Jones), a clockwork assassin, Kroenen (Ladislav Beran), and a multitude of duplicating demons, Hellboy offered Del Toro's effects team a variety of challenges, producing 800 visual effects on a modest budget of \$10.5 million chief among them. The film opened to acclaim and saw a successful run at the boxoffice, leading Revolution Studios to greenlight a Hellboy sequel. But when Sony Pictures decided to end its partnership with the studio, Revolution folded, leaving the proposed Hellboy II project orphaned like the infant protagonist of the first film's opening sequence.

Enter Universal Pictures, which picked up the project and set Del Toro and his collaborator, Hellboy comic creator Mike Mignola, to work on a screenplay. Del Toro continued to revise the script while working on *Pan's Labyrinth*, conceiving an effects-laden production that would take advantage of approaches used in that Oscar-nominated film. *Hellboy II: The Golden Army* reached roughly 1,100 effects shots, and required a combination of makeups, animatronics and computer animation to create an impressive range and number of fanciful, paranormal characters.

Del Toro distributed the work among many effects suppliers, including Hellboy veterans Mike Elizalde of Spectral Motion — which designed and executed an unprecedented number of practical characters — and DDT Efectos Especiales, in Spain, which created a young Hellboy makeup for a flashback sequence that opens the film. Visual effects supervisor Mike Wassel oversaw shots produced at Double Negative, working with digital effects supervisors Adrian De Wet, Andrew Chapman and Justin Martin. Other shots were subcontracted to Cube FX, The Senate, Baseblack, Lip Sync, Hatch FX and Copenhagen's Ghost Visual Effects Studio.

Del Toro shot for 130 days at the new Korda Studios, still under construction outside Budapest, Hungary. "We were the first film to use the place," stated Mike Wassel, "and we were the only production there. To have the entire studio to ourselves was fantastic. We were able to spread out over the whole facility."

Hellboy II: The Golden Army begins with adoptive father Professor Broom (John Hurt), the head of the Bureau for Paranormal Research and Defense, telling a young Hellboy a fairy tale about the creation of the golden army: large, robotic soldiers of solid gold — controlled by a three-piece crown

Paranormal Parade

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— who act as defenders of the elven world of Bethmoora, ruled by King Balor and his children, Prince Nuada and Princess Nuala.

For the young Hellboy makeup, Del Toro was inspired by Mike Mignola's comic book story *Pancakes*, in which the character is presented as a scrawny figure with arcing horns. "Guillermo's first idea was to mix together the character in *Pancakes* with Ron Perlman's Hellboy makeup and a normal child," noted David Martí of DDT Efectos Especiales. "But anything that was too similar to Ron's Hellboy makeup looked very bad. It looked like a young Frankenstein. We thought we should start with the look of a child, but a demon child. It still had some elements of the full-grown Hellboy makeup, but we didn't base the character on that." Martí tested the design on his Efectos Especiales partner, Montse Ribé; and when Del Toro saw her in the makeup, he asked that she play the part in the film. "She hadn't done anything like this before; but in the first versions of the script, there wasn't much dialogue for the character, so Montse said, 'Yeah, I can do it.' But then, after shooting began, the scene began to change, and every time Montse got a script there was more and more dialogue!"

As Broom tells the story of the golden army, the young Hellboy imagines the scene. Though the sequence was all-digital, created by Ghost Studio, it was designed to look like a marionette scene, with wooden puppets representing the various characters and sets that looked like tabletop miniatures. The puppet theater look served two purposes: it suggested the mind's eye of young Hellboy's imagination, and it facilitated a simplified, less costly production design. "If we had tried to photograph this sequence live-action," noted Mike Wassel, "it would have been an enormous proposition. Telling the story digitally, with puppets as our characters, was a way to manage the overall complexity of the images and keep the cost of the sequence in check. So we used the aesthetic of tabletop miniature photography, but hyper-realized in its execution. Primarily we were focused on shallow depth-of-field, and keeping the scale of the textures appropriate; but to give the images a broader scope, we incorporated other photographic idiosyncrasies that would be difficult to accomplish using actual miniatures."

The fairly tale ends with King Balor making peace with mankind and burying his golden army. The film then shifts out of the miniaturized fairy tale and into the present-day real world, where the banished Prince Nuada (Luke Goss) plots to reassemble the three-piece crown, activate the golden army, and launch it against the human world. That quest takes him to an auction house in Manhattan, where one of the three crown pieces is to be sold.

Makeup designs for Prince Nuada, King Balor (Ray Dotrice) and Princess Nuala (Anna Walton), were first conceived as character sketches drawn by Del Toro in one of the little leather notebooks he carries for jotting down ideas and illustrations. In addition to white faces and long, snow-white hair, final elven designs featured facial scars and, for the male elves, pointed tips on their ears.

After some experimentation, Spectral Motion opted to fit Anna Walton with only a minimal scar that stretched over her nose and across her cheeks. “We tried prosthetics on her,” said Mike Elizalde, “but they didn’t serve any purpose other than to make her look grotesque.” For Prince Nuada’s more sinister, scarred look, special makeup effects artist Bart Mixon applied prosthetics that extended from Luke Goss’ hairline down to his chin. The prosthetics applied to Ray Dotrice were more extensive, still, suggesting an aged version of the king’s offspring. “He shares the white skin tones and hair, but Balor differs from the other elves in that he has a foam latex antler-like thing on his head that emulates a crown, but is actually an organic part of him.”

Prince Nuada disrupts the auction proceedings in a sequence that introduces one of the film’s key practical characters, Mr. Wink, the prince’s enormous, muscle-bound henchman. As designed, Wink had leathery bluish-gray skin and short tusks that jutted from just below the corners of his mouth. Spectral Motion realized the character as a seven-foot-eight-inch-tall, four-foot-wide, 130-pound suit worn by veteran suit performer Brian Steele. “Brian’s our giant creature guy,” said Elizalde, “and he is able to live in this type of suit as long as it takes to get the job done. But in this case, because of the weight of the suit, it was really testing the limits of his abilities.”

To cope with the character’s enormous size, Spectral Motion built the Wink suit in multiple pieces — legs, torso, arms, hands and head — using lightweight, open-cell-structure foam, covered with a more dense foam latex skin. The open-cell foam not only lightened the suit, it allowed air to flow through it, while wicking moisture away from the performer. “Brian doesn’t like to wear a cool suit beneath these characters,” said Elizalde, “so we had to come up with other ways to keep him cool. We kept him hydrated and regulated his temperature by giving him a lot of cool drinks, which he would take in through a big tube that went into the mouth area. We also made sure that we could get the hands off easily, because they are the radiators—you can cool yourself off pretty quickly if your hands are in the open.”

One of Wink’s hands resembles a studded mace when curled into a fist, and then becomes a powerful weapon when hurled out on a chain. Spectral Motion animatronics designer Mark Setrakian designed a servo-driven hand apparatus that could be extended on a chain and retracted through an opening in the wrist. The device was controlled remotely and was self-contained and untethered, in deference to Del Toro’s dislike for cables. Setrakian designed facial features to function by remote, as well. Three operators were required to control all the suit’s animatronics: one on the mouth and jaw, another on the character’s single eye, brow and lower face, and a third on the mechanical hand.



After lifting Hellboy from comic book page to the screen in 2004, director Guillermo Del Toro began work on a sequel to his original Hellboy, writing the screenplay with Hellboy creator Mike Mignola. Filmed at the newly opened Korda Studios in Hungary, Hellboy II: The Golden Army was replete with fantastic paranormal characters, requiring a close and spirited collaboration between Del Toro, creature effects supervisor Mile Elizalde and his crew at Spectral Motion, visual effects supervisor Mike Wassel, and the visual effects team at Double Negative. Support vendors based in Los Angeles, London and Copenhagen also contributed to the film’s 1,100 effects shots.



Mike Elizalde applies the Hellboy makeup to actor Ron Perlman, a task that took two and a half hours to complete each shooting day. Spectral Motion technicians recast Perlman's head to obtain a fresh and up-to-date lifecast, on which Matt Rose – the designer of the original Hellboy makeup – resculpted the character. Delighted with Hellboy's look in the first film, Del Toro insisted that the new makeup duplicate the original exactly, right down to its slightly asymmetrical countenance.



Del Toro turned to frequent collaborators David Martí and Montse Ribé of DDT Efectos Especiales in Spain to design and execute a makeup for a flashback prologue sequence featuring Hellboy as a young boy. When attempts to base the makeup on Ron Perlman's adult Hellboy look produced unsatisfactory results, the makeup artists started from scratch, finding inspiration in the character as he appeared in Mike Mignola's comic book story, Pancakes. Montse Ribé works on the young Hellboy sculpt.

Battles between Wink and BPRD agents featured CG enhancements by Double Negative. “The animatronic hand on the Wink suit couldn’t be used as a practical weapon,” noted Mike Wassel, “so, in fight scenes, the suit was fitted with a non-articulated stunt hand. If the shot called for the hand to perform a specific gesture or action, we would take over from the practical mace with a CG replacement.” Double Negative also used digital techniques to expand the range of the practical head. “In one particular closeup, we replaced the muzzle, leaving the eyes and the rest of the head intact. We animated the tongue and gave the mouth additional articulation.” For Wink actions impossible for a human to perform, Double Negative re-created the character entirely in CG.



After he saw photos of Ribé in a test of the makeup, Del Toro convinced her to play the part in the film. Martí applies the young Hellboy makeup to Ribé.

The film shifts from the auction house to the Bureau for Paranormal Research and Defense. Del Toro had wanted to include, in the original Hellboy, an establishing shot of the BPRD headquarters — an aerial view, as if from a helicopter, with the New York skyline in the distance — but the shot never came to fruition. For the second film, Del Toro tasked Hatch FX visual effects supervisor Deak Ferrand with creating the shot. Ferrand gathered pictures of the Prague building that had stood in for the headquarters in the first film, and then produced a matte painting of the building that was projected onto a 3D survey model provided by production. “There wasn’t any aerial footage of this,” said Ferrand, “and so I painted the entire shot. But it doesn’t feel static at all. It’s projected onto geometry and really moves in 3D.”

Once inside the BPRD headquarters, a long Steadicam shot proceeds down a corridor, revealing three of the agency’s strange and otherworldly research subjects — each of which was computer animated. The ‘faceless cave berserker’ was based on a design Mike Mignola had originally conceived for the Sammael demon in Hellboy, rejected when Del Toro went in a different direction for that character. Spectral Motion sculpted the berserker as a 24-inch maquette, which was subsequently sent to Double Negative to be used as reference for the computer animated creature. “The faceless cave berserker is about seven feet tall,” explained Double Negative animation supervisor Eamonn Butler. “He’s like a big gorilla, with short legs and long, slightly gelatinous arms that look as if they are filled with water bags. He’s covered in leathery, bumpy skin, and has tentacles and a carapace shell that peels back to reveal his face.”

In the shot, which ran close to 1,000 frames, BPRD agents grapple with the uncooperative berserker. To capture the live-action, Del Toro shot agent performers struggling with Brian Steele in a green suit. “That was one of the most challenging shots from an integration standpoint,” said Butler. “The performer in the green suit was much smaller than the berserker would be, and so the agents’ arms and hands interfered with the space where the CG character would be struggling. To place their

hands back on top of the berserker, we had to replace the BPRD agents' arms with digital arms, which we tracked to their actual bodies."

As the Steadicam proceeds down the corridor, it reveals a creature dubbed the 'Lovecraftian entity' — a nine-foot-tall, tentacled behemoth with giant pincer arms and an inverted squid head, modeled by Double Negative from a scan of a Spectral Motion maquette. As with the berserker, a green-suited performer stood in for the Lovecraftian entity in the live-action plate featuring BPRD agents wrestling with the creature. "Again, we had massive integration issues," said Butler, "because we had people holding down a guy in a green suit, and the guy didn't look anything like the character. So we ended up replacing a lot of the limbs on the agents in that shot, too. All of the work came down to making it look like the humans were actually holding him."

The final creature introduced in the corridor is a baby troll, a younger version of trolls seen later in the film. Double Negative modeled the baby troll using photographic reference of a Spectral Motion suit as a point of departure. "We modeled a full-grown troll first," said Butler, "and then scaled down the body and found a ratio for the head and body that made it look like he was young."

The tour of BPRD headquarters is interrupted when pyrokinetic Liz Sherman, arguing with Hellboy inside his vault, blows off the door in anger. So pleased had Del Toro been with the Hellboy makeup for the first film — down to its slightly asymmetrical look — he was adamant that no changes be made to it for the sequel. To obtain a fresh and current lifecast, Spectral Motion recast Ron Perlman, and then Matt Rose — who had sculpted the original Hellboy makeup — resculpted the character on the new lifecast. Mitch Devane executed the final texture on the resculpted pieces, while Jim Hogue painted the new prosthetics, which Mike Elizalde and Anthony Parker spent up to two-and-a-half hours applying to Perlman on set.



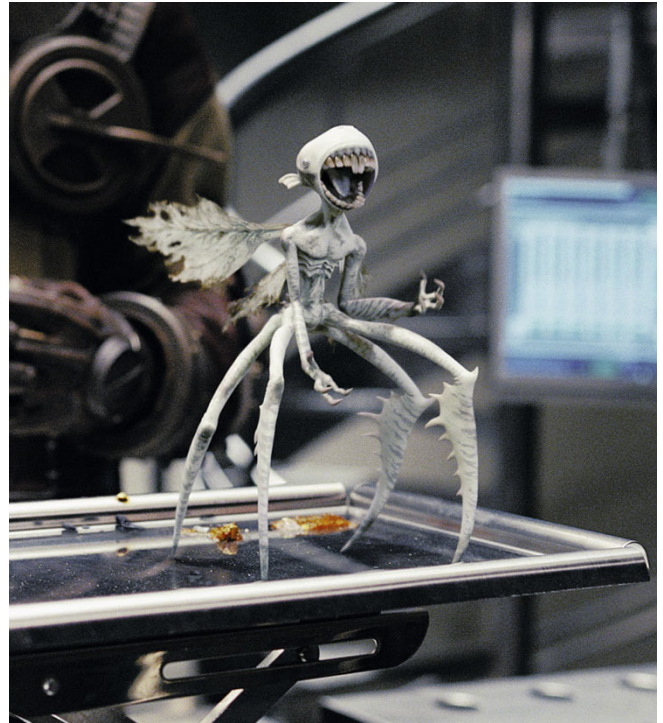
In the present day, the elven Prince Nuada plans an attack against mankind with the help of Mr. Wink, his lead henchman. Wink was realized in most shots by performer Brian Steele in a 130-pound Spectral Motion suit. Double Negative tracked a CG mace hand to the suit for shots of Wink hurling the weapon at opponents.

Del Toro insisted that Abe Sapien's cosmetic appearance, too, exactly match what it had been in the earlier film; but Spectral Motion artists rethought their approach to achieving the look, switching from applying individual prosthetic pieces to performer Doug Jones to fitting him in a complete Abe Sapien suit. The suit approach cut down on application times, and also facilitated a large number of shots in which the character would appear bare-chested. As in the first film, the aquatic Abe's home at the BPRD is a large water tank attached to Professor Broom's library. Shots of Abe swimming in the tank were slated as CG to avoid the danger of a heavily suited performer having to swim underwater. Animator Rob Hemmings animated the digital Abe's swimming motion, and then digital double CG lead Pieter Warmington and lead compositor Fred Place integrated the character into the practical on-set tank with CG water and particulate matter.

The BPRD is called out to investigate a mass killing at the Manhattan auction house. There, Hellboy, Liz, Abe and other BPRD agents wander the ravaged rooms, finding a peculiar, orange-brown substance on the floor — soon revealed to be the remains of people who have been devoured, digested, and defecated by swarms of small winged creatures called tooth fairies. A low buzzing builds in volume, warning of a new attack on the BPRD crew. "There are literally thousands of tooth fairies in these attack shots," said Eamonn Butler, "swarming around Hellboy, Liz, Abe and the BPRD agents, trying to kill them." Double Negative senior visual effects producer Steve Garrad, animation lead Anders Beer and digital effects supervisor Andrew Chapman were present at Korda Studios to collect camera data, lidar information and photographic reference for the sequence.

On set, the crew simulated the interaction of the tooth fairies with three BPRD agent victims. "We had air bladders underneath the actors' costumes," noted Mike Wassel, "which were used to rapidly vibrate the cloth, simulating the activity of the tooth fairies under the clothing. We also used ping-pong balls attached to the costumes when actors needed a physical object to handle. In postproduction, they were removed and replaced with our CG tooth fairies."

Working from concept art by Mike Mignola, character designer Francisco Ruiz Velasco conceived the tooth fairies as nine-inch-tall exoskeletal characters with four legs, two arms, semi-translucent dragonfly-like wings and a small mouth that, in attack mode, opens wide, with lips curling back to reveal rows of sharp teeth. To build the tooth fairy model, Double Negative worked from photographs and 3D scans of three oversized maquettes sculpted and painted by Solution Studios



After an attack at an auction by thousands of flesh-eating tooth fairies, BPRD supervisor Johann Krauss – an ectoplasmic entity housed in a mechanical suit – examines one of the voracious creatures. Double Negative worked from photographs and 3D scans of oversized maquettes to build the tooth fairy model.

in London. Animators then developed keyframed crawling, walking and flying motion tests. “We leveraged that keyframe animation to create a library of animated actions that we could plug into scenes,” said Eamonn Butler. Double Negative wrote a particle-based, procedural animation system in Maya, called Swarm, for shots of swarming tooth fairies. “With Swarm we can draw motion curves or paths and the particles will fly along those curves — and they’re smart enough to know when they’ve hit another character or a surface to land on. Depending on what they intercept, they switch modes, going from a flying cycle to a crawling or biting cycle.”

Another proprietary tool, Director, enabled animators to create the masses of fairies without taxing computer memory and power. “Computers will strain if you load them up with more than a certain amount of geometry,” observed Butler. “Director allowed us to switch between the animated rig and a geometry cache, which is just the animating shell, with the rig stripped out. We couldn’t actually reanimate the character when it was cached out, but it gave us a visual reference for what the character was doing.” Using the geometry cache approach, animators laid fairies into the scenes in layers — foreground, midground and background. “We might animate three background fairies, for example, and cache that, then move onto a foreground layer. Later, we might decide that we needed to revisit the background layer animation. We could just switch back from the cache to the animated rig and work them up again.”

During the attack, Hellboy pushes a nine-foot-tall fertility goddess statue through a wall, crushing the fairies on the other side as Liz incinerates them with her flames. Joss Williams’ special effects crew rigged the statue’s fall as a mechanical gag. The shot of its crashing through the wall near Liz, Abe and other agents was one of only two motion control shots in the film. “For safety, we needed to photograph the mechanical effect separately from the actors,” Mike Wassel explained, “but maintaining Del Toro’s shot design required the cameras to be in constant motion. The solution: reverse-engineered motion control, which allowed us to shoot unpredictable action wild. In this case, a Super Scorpio crane was used for the A camera, with B and C on sticks, and D camera on the Steadicam. Once selects were made, we tracked the camera movement in 3D and output synthetic axis motion control data to the Milo. From there, it was a simple matter of running the move for the foreground actors against greenscreen.”

Blown out an auction house window with the force of Liz’s pyrotechnics, Hellboy lands on a police car, crushing it even as BPRD chief Tom Manning (Jeffrey Tambor) is in the midst of an interview, denying the existence of Hellboy and the bureau. A mechanical rig was set up to crush the top of the police car and blow out the windows. Double Negative inserted a Hellboy digital double into the scene.

With Hellboy’s secret out, a BPRD higher-up, Johann Krauss (voiced by Seth MacFarlane and portrayed by suit performers John Alexander and James Dodd) is sent to manage the situation. A gaseous entity contained in what resembles an antique diving suit,



The BPRD team investigates the auction massacre, using Shufftein goggles to penetrate the human disguise of a fragglewump troll. To realize the creature practically, Spectral Motion fitted Brian Steele with a head appliance

with heavy boots and a glass dome helmet, Krauss was originally designed by Mike Mignola for the Hellboy and BPRD comic book series. Del Toro reworked the design for the film, and Spectral Motion realized the practical aspects of the character, such as the diving suit and the smoke swirling within the glass dome. “To create that look,” stated Mike Elizalde, “we relied on the old headless horseman trick: John Alexander and James Dodd wore a rig that raised the suit’s shoulders to their nose level, and then the contained glass dome sat above that.” Tubes were installed to feed smoke into the dome, and a suction fan kept the smoke moving.

Krauss’ emotional state is punctuated with bursts of smoke venting through valves on the collar of his helmet, produced via gas canisters located on a belt around the waist of the suit. “He wore a utility belt like Hellboy and all the other BPRD members wear,” said Elizalde. “In one of the pouches of that utility belt we had an air-duster, which produced a visible cloud of gas. We had a line going from that up to the ports in the collar of the helmet.” Spectral Motion designer Jurgen Heimann designed a device that, when placed on top of the air-duster, activated the spray lever remotely, producing venting collar smoke on cue. Dome smoke and the circulation fan were also activated through radio control.

At several points in the film, Krauss exits the suit in a stream of swirling smoke to enter and reanimate specific objects or characters. Largely a digital effect, the suit exits were initiated practically, with small tendrils of gas emerging from the suit’s fingertips via valves that resembled those on a saxophone or clarinet. Double Negative picked up the effect from there, generating fluid simulations for the digital smoke effect and cloth simulations for Krauss’ collapsing diving suit. “We did a digital version of Johann Krauss in his suit for deflation and inflation scenes,” said Eamonn Butler, “where he’s coming in and out of the suit. For shots of the suit deflating, we did a cloth simulation on a hand-animated version of the suit. We had another version where he’s completely out of his suit, all made of ectoplasm.”

To create the ectoplasmic Krauss, Double Negative generated a digital double rigged with fluid simulation emission sources. “This was supposed to look as if Krauss was struggling to maintain his basic human form,” observed Butler, “even when outside his suit. The problem with a smoke simulation was that it behaved like real smoke; and that meant that the smoke just dissipated when we moved the digital double around like a real human. Working very closely with CG effects lead Eugénie von Tunzelmann and using our in-house fluid simulation software Squirt for

featuring animatronic eyes and brows, and a bulbous body suit that concealed mechanisms used to manipulate its spindly arms. Spectral Motion used bunraku puppetry techniques to make the fragglewump ambulatory, attaching the creature’s legs at Steele’s hips and feet so that the performer’s walking movements translated to the character’s insect-like limbs.



The fragglewump divulges the location of the troll market, a netherworld populated with all manner of paranormal creatures. In one troll market scene, Johann Krauss enters a barbershop to question the ‘Cronie’ as he gives a shave to a character with a strange, baby-like growth on his torso. Brian Steele wore a Spectral Motion foam latex suit to portray the Cronie throughout the scene. For a final shot in which Hellboy, frustrated by the interrogation, punches the Cronie, Double Negative animated a digital version of the character soaring through the air and landing in a pot of hot oil.

pyroclastic simulations, we realized that to make it look like we were animating a person made of smoke, we would need to bend and break the digital double rig. So we added deformers and special controls that allowed us to move the digital double in ways that a real human body wouldn't be able to. If Krauss extended his arm, we would extend it way out to a point, and make it curl and flow as if it were smoke. We hand-animated all of that, and that animation drove the smoke sim."

The film returns to Prince Nuada as he attempts to enter the royal chamber at Bethmoora, with the intention of murdering his father, the king. Stopping him is the chamberlain, another of Spectral Motion's creations, designed by Chet Zar. "The chamberlain is a really unusual, surreal character," noted Mike Elizalde, "with a head that looks a bit like a big thumb." The character, played by Doug Jones, featured animatronic eyes set in a prosthetic appliance, as well as long, spindly animatronic arms with gesticulating fingers.

Prince Nuada storms into his father's throne room and confronts the royal bodyguards, called the Butcher Guards, played by live performers in white, elven makeup. Slicing through them with a sword, Nuada assassinates King Balor and takes possession of the second piece of the golden army crown.

Meanwhile, the BPRD goes in search of a troll market to track down the instigator of the auction house catastrophe. To locate the market, Hellboy and Abe don bizarre, multi-lensed, telescopic-looking glasses, called Shufftein goggles, which allow them to see through the magical effects the trolls use to disguise themselves when outside the fairy realm. Wandering beneath the Brooklyn Bridge, Hellboy and Abe encounter a bedraggled old woman, whose true troll identity is suggested in animated enhancements of the live-action performance. "We created a cartoon-like exaggeration of the old woman's features as she attempts to eat a small kitten," said Mike Wassel. "Her nostrils widen, her eyeballs expand and bulge out of her head, and we hyperextended her jaw as she put the kitten into her mouth."

The Shufftein goggles reveal the old woman to be an unusual looking creature called the fragglewump. Designed by Spectral Motion's Constantine Sekeris, the fragglewump had a large head with wide-set eyes and a small chin, spindly arms, and slender legs that bent like grasshopper limbs from each hip. Though the fragglewump was not at all anthropomorphic in design, Spectral Motion ingenuity allowed for it to be realized as a practical effect.

Atop his own head, Brian Steele wore an outsized fragglewump head, which had animatronic eyes and brows actuated by remote control to give the character a full range of expression. Steele's own mouth movements actuated lip prosthetics, enabling the character to speak lines of dialogue. The bulbous body of the creature's suit concealed Steele's arms, as well as the mechanisms he



Prince Nuada unleashes upon New York the 'elemental,' a 100-foot-tall plant creature that sprouts from magic beans. Double Negative fashioned the all-CG creature in two layers, one comprising the squid-like body, and a second made up of ancillary vines and leaves. Main body animation drove the procedural animation of the secondary foliage. To shoot scenes of the elemental wreaking havoc on the city, production built a backlot set that was deconstructed and dressed in various stages of damage and disrepair. Double Negative surrounded the set with digital environments, and used rigidbody simulations to suggest the physical destruction of streets and structures.

manipulated to control the fragglewump's spindly arms. Long-fingered hands were operated remotely. Spectral Motion turned to bunraku puppetry techniques, which Del Toro had employed for the fawn's legs in *Pan's Labyrinth*, to mobilize the creature's insect-like legs. "The legs were attached mechanically at Brian's hips," stated Elizalde. "From the hips, they jutted out at an angle, came down, and attached to Brian's feet. Whenever he moved his feet, the legs would mimic whatever his feet and legs were doing — so he could actually walk as the character." To disguise Steele's real legs, the performer either wore black tights, which tended to disappear in dark environments, or green tights that could be digitally removed in postproduction. "The result was a character that deviated far from the anthropomorphic, but clearly was not CG. It was very convincing — and one of the weirdest things I have ever seen."

Contact with the fragglewump enables Hellboy and the BPRD team to locate a large, mechanical door that leads to the legendary troll market, an enormous practical set constructed inside a mine cavern in Hungary. As conceived by Del Toro, the troll market is a vibrant, busy environment filled with the hustle and bustle of fantastic creatures, many of which were achieved as practical gags by Spectral Motion.

London-based makeup and creature designer Nigel Booth contributed a fish vendor character — literally, a vendor that had the face of a fish — based on an illustration by Del Toro. "The character was essentially a seated man in a suit," observed Booth, "made up of several animatronic elements." Fittingly, the performer inside the fish suit was Brian Herring. "Brian wore a padded undersuit, which was covered by a fish-stained over garment. The head was an animatronic with silicone skin, secured to Brian's head via a quick-release skullcap. The head was capable of basic lip-sync, full eye rotation and eye bulge." Mechanical supervisor Adrian Parrish designed and built all of the animatronic elements, including four cable-controlled tentacles.

In the course of the troll market sequence, Hellboy enters a barbershop, where a character with a strange, baby-like growth on his chest is getting a shave by the flabby, bumpy Cronie — another Spectral Motion foam latex suit, worn by Brian Steele, based on a maquette by Matt Rose and Chad Waters. When Hellboy decides the interview is going nowhere, he punches the Cronie, at which point Double Negative took control of the shot, animating a digital version of the character flying through the air and landing in a pot of scalding oil.



When Hellboy loses his temper in an argument with Krauss, breaking his superior's helmet, the character emerges from his suit in a gaseous cloud. Though Spectral Motion built Krauss' mechanical suit and smoke-filled helmet, all shots of Krauss in vaporous form fell to Double Negative, which generated a digital double rigged with fluid simulation emission sources. Deformers and special controls allowed animators to move the digital double unnaturally – elongating an arm beyond human capacity, for example – and that hand-animation drove the curling, flowing action of the smoke simulation.

Elsewhere at the market, Abe follows Princess Nuala into a map shop run by Cathedralhead. The name says it all: the shop owner's head is a small medieval cathedral that extends up from his brow, while the bottom of his face appears to be stone crags with black eyes and just the suggestion of a mouth. Del Toro did a rough sketch of the character in one of his little leather books. Chet Zar refined the design, used as the basis for a Spectral Motion head appliance worn by Doug Jones.



The BPRD team travels to Giants' Causeway in Northern Ireland, gaining entrance into the elven realm of Bethmoora through the torso of a 40-foot-tall stone giant awakened by a legless goblin. Double Negative animated the stone giant, laying rigid-body and cloth simulations over keyframe creature animation to create a landslide of small rocks and soil displacement as the giant shifted position. Double Negative then integrated the digital creation into plates filmed on location in Hungary, expanding the terrain with a digital cyclorama built from plate photography shot in Northern Ireland.

Double Negative computer generated other background market characters, there solely to create ambience and atmosphere. Constantine Sekeris produced drawings of 'striders,' large, long-legged characters resembling a hybrid elephant and giraffe, and those designs were subsequently revised and refined by Solution Studios, which provided maquettes. Double Negative then realized the characters in CG. "Even though the striders are just in the background," commented Eamonn Butler, "we did about six months of work on these characters. To make them as realistic as possible, we did very detailed textures on them, and we hand-animated bulging muscles — and they ended up in the background of the movie! Guillermo did a lot of that. He would put a lot of work into stuff, and then only use it sparingly. It was all about creating an ambient atmosphere. Everywhere you went in this movie was rich with life and character."

Also enlivening the troll market are two-headed monkey-like creatures called bogarts. Measuring just eight inches tall, the bogarts resemble a kangaroo, with folded-up legs, small pouch on the abdomen and fleshy protuberances on the head that suggest hair. Del Toro fell in love with the character, as sculpted by Mitch Devane, and the original limited plans for it bloomed into a more significant presence in the market. Double Negative animated a scene in which three bogarts gather and communicate, clicking their heads together in a sort of Morse Code speech.

Prince Nuada dispatches Wink after the mischievous bogarts inform him of the BPRD's presence in the troll market. Wink follows Abe into the map shop, where the two begin to tussle. Parts of the fight that could not be achieved by performers in suits — such as Wink throwing Abe around the shop — were animated by Double Negative. The action shifts back to live performers when Hellboy enters the fray, with Ron Perlman and Brian Steele performing many of the fight maneuvers; but the limitations of the Wink suit necessitated some digital enhancement. "One particular shot called for Wink to rise up behind Hellboy," said Mike Wassel. "It sounds simple — but it would have been physically impossible for Brian to perform that action in the suit." Double Negative realized the action with its digital Wink double. The digital Wink also featured in the fight's conclusion, in which Hellboy feeds the henchman into a large meat-grinding machine. Although a mechanical prop was on set, it was replaced with a CG version for shots of CG Wink interacting with the grinder.

With Wink's demise, Prince Nuada returns to New York to confront Hellboy and the BPRD agents beneath the Brooklyn Bridge. There, he takes a small glowing bean from a pocket, whispers instructions to it, and throws it into the sewer, where it grows to a massive plant-like creature called the 'elemental,' designed by Francisco Ruiz Velasco as a mass of featureless vines and leaves. Through reworking, the elemental came to resemble a botanical squid-like creature, sculpted in maquette form by Solution Studios. "It had multiple long, elegant limbs," said Eamonn Butler, "which acted like tentacles, and the head was a sort of inverted squid body with two small slits for eyes and a representation of a mouth."

CG lead Cristophe Ahmand and animation lead Colin McAvoy collaborated to build the elemental in two layers: one resembling a Jolly Green Giant with limited details, and a second comprised of vines and leaves. Main body animation drove the procedural animation of the secondary leaves and vines. "Every time the elemental drops a foot," explained Butler, "there's a shudder of leaves that travels through his body. Colin was very conscientious about making sure the creature didn't move too fluidly, because that wouldn't drive the leaves at all. So when he put a foot down, there was a big thump, and you would see his tentacles actually take a hit. The shoulders adjusted very sharply, and that movement was augmented by the leaves and vines and so forth."

The plant rises to roughly a 100-foot height, sending debris and cars everywhere as it moves through city streets. To shoot the action, production built a set on Korda Studios' backlot representing a U-shaped area beneath a stanchion of the bridge and nearby Brooklyn Bridge Park. The practical set was deconstructed and dressed in various stages to reflect the mounting level of damage inflicted by the elemental. Once principal photography was completed, Mike Wassel and Double Negative environmental lead Gawain Liddiard spent a week in New York photographing aerial plates of the bridge and capturing material to digitally reconstruct the bridge and the surrounding area of the city. Rigid body simulations, which required extraordinarily long computations, created the physical destruction of the city streets and structures.

Hellboy ends up perched atop a hotel sign, facing the elemental at eye level, poised to shoot it with one of his beloved guns. Prince Nuada arrives on the scene, and tries to persuade Hellboy to spare the elemental's life and join him — an offer Hellboy answers by killing the creature. The forest god's head opens, spilling blood down the creature's body and onto the ground, transforming the area into a moss-covered forest floor. Working in Photoshop, Deak Ferrand at Hatch FX produced lavish concepts for the effect, which was realized both practically and digitally. "The ground level was built as a practical set that the actors could walk on and interact with," Wassel elaborated. "We transition



To avoid the costly process of digitally removing an actor's legs, Spectral Motion created the legless goblin – who gets around via a wheeled cart – as an entirely in-camera gag. Performer John Alexander laid flat on the cart, stomach down, his legs extended back into it and his back arched up to raise his torso over the front wheel. A foam latex prosthetic that extended from his neck down to his belly made it appear as if the character was angled forward, rather than backward. Alexander steered the rig with his feet, hidden in buckets in the back of the cart.

into CG as the creature's body extends up along the destroyed building; and then the aftermath scene was photographed practically, with little or no CG enhancement."

Back at BPRD headquarters, Prince Nuada again confronts Hellboy, spears him in the chest, then grabs Princess Nuala and returns to Bethmoora. Unable to remove the spear tip without killing Hellboy, the entire BPRD team travels to Giants' Causeway in Northern Ireland, gaining entrance into Bethmoora through a stone giant awakened by a legless goblin. The goblin began as a maquette sculpted by Matt Rose, who imagined a being perched on a wheel with small wooden crutches with which he pulled himself around. Spectral Motion endeavored to achieve the creature practically, so that production could avoid the costly process of digitally removing an actor's legs. "To keep this from costing a million plus," Mike Elizalde explained, "we redesigned the character a little bit so that the goblin would be attached to a cart that he pulled behind him." Spectral Motion's Scott Millenbaugh and Jurgen Heimann constructed the cart, upon which John Alexander lay on his stomach, his legs extended back into it and his back arched up to raise his torso over the front wheel. "He steered the rig with his feet, hidden in some buckets in the back of the cart, and he wore a prosthetic from his neck down to his belly. The belly prosthetic made it look as if he was angled forward, when in fact he was angled back into the cart."

The awakened 40-foot-tall stone giant was primarily a digital creation, integrated into a small area of farmland in Hungary, which production mocked up to look like the Irish countryside. To expand the scene, Adrian De Wet traveled to Northern Ireland and shot ground plate photography, from which a cyclorama was constructed. "When the characters first encounter the stone giant," explained Mike Wassel, "he's lying on his back, partially buried. Once the goblin calls him, he sits up, pulling himself out of the ground and revealing the doorway in his chest." Animators laid rigid-body and cloth simulations over keyframe creature animation,



Within Bethmoora, Hellboy and his colleagues encounter the Angel of Death, a mystical creature with a bony, fan-shaped head and four undulating wings, each featuring a row of eyes running along its leading edge. Despite the character's bizarre appearance, Del Toro mandated that no part of the Angel of Death – not even the complex wings – would be created through digital means. Spectral Motion extrapolated on Del Toro's own Angel of Death sketches, and then sculpted facial appliances that were worn by Doug Jones.



creating a landslide of small rocks and soil displacement as the stone giant moves.

Through the stone giant's open chest, Hellboy and his colleagues enter Bethmoora, created through a combination of small stage sets and fanciful matte paintings. Once inside, the team locates the Angel of Death, a mystical creature who can safely remove the spear tip from Hellboy's chest. In one of his leather notebooks, Del Toro had sketched the Angel of Death as a skeletal character with a broad, bony forehead that extends out in a fan shape, and four wings, each with a row of eyes running along the ridges.

Spectral Motion mechanical designers fitted the wings with mechanisms to make them fold, unfurl and flap, and mechanized the eyes to change angle as the wings extended and retracted, maintaining a configuration parallel to the ground. All of the eyes could move in unison or individually, and could blink sequentially, creating a cascading effect. Spectral Motion artists dressed the wings with feathers made of polyvinyl, with stiffening wires inserted to maintain rigidity. Scott Millenbaugh works on an Angel of Death wing under construction.

Despite the character's bizarre appearance, Del Toro mandated that no part of the Angel of Death — not even the complex wings — would be created through digital means. At Spectral Motion, Norman Cabrera extrapolated on the designs, sculpting facial appliances that would be worn by Doug Jones, including the fan-shaped forehead and teeth that extended out beyond pulled-back lips. Mark Setrakian and Bud McGrew designed mechanics that would make the large, multi-eyed wings operational. The wings were built to fold, unfurl and flap, yet were light enough for Jones to wear while performing. The eyes were installed along the rigid frames of the wings, and were mechanized to change angle as the wings extended and retracted. "The eyes were placed on mechanisms that allowed them to rotate in relation to the wing movement and remain parallel to the ground," said Elizalde. "Regardless of the wing position, the eyes remained level; and all the eyes could look around in unison or individually. To give it a little extra touch of magic, Mark Setrakian also incorporated a card that would make all the eyes blink sequentially, creating a cascading effect." Fred Fraleigh dressed the wings with feathers made of polyvinyl, with stiffening wires inserted to maintain their rigidity.

Spectral Motion completed the Angel of Death just two weeks prior to shooting. "It was breathtaking to see it on set," observed Elizalde. "Literally, when we walked the Angel of Death onto the set, everybody gasped and stopped what they were doing. It was a great moment."

Hellboy, Liz, Abe and Krauss find Prince Nuada and Princess Nuala in the golden army chamber—a two-part environment made up of the egg chamber, where the dormant golden army soldiers lie folded into egg shapes, and a central ziggurat. While two practical eggs were built for actors to walk past on the set, Double Negative created wider shots of the chamber filled with hundreds of eggs, as well as shots of the eggs unfolding into full-size activated golden soldiers when Nuada assembles the three pieces of the magical crown and places it on his head.

The golden army soldiers received their first imag-ining at Spectral Motion, where Taishiro Kiya created designs and a digital model in Maya suggesting huge mechanical creatures with visible gears and cogs. In an evolutionary process led by Double Negative animation lead Jay Davis and CG lead Graham Jack, those designs were subsequently reworked in favor of a bulkier, more imposing and impressive soldier. Double Negative produced the entire golden army digitally, initially planning to hand-animate all of the characters' moving gears and cogs. "We soon realized that was crazy," said Eamonn Butler. "It would have taken us months to do that all by hand." As an alternative, Jack

explored techniques for streamlining the animation process, including a procedural approach that would link the movements of the cogs to the motion of the soldier's limbs. "Every time a character's legs moved, certain cogs would move in certain directions. Other parts of the mechanism were activated by the arms, chest, and so forth. All of the internal mechanisms were completely automated; but if we ever needed to, we could go in and hand-animate stuff on top of what was there."

The activated army approaches the ziggurat en masse and engages Hellboy and Johann Krauss in combat. Wire rigging enabled stunt performers to simulate Hellboy's paranormal leaps from soldier to soldier as he shoots and clubs them, while Double Negative generated rigid body simulations to create robot destruction debris. Despite the severity of the damage Hellboy inflicts on them, the soldiers are able to regenerate immediately. Sensing the hopelessness of the fight, Princess Nuala exploits the physical link that binds her fate with that of her brother; she commits suicide, and Prince Nuada collapses, as well. With the death of the prince, the crown is rendered useless and the golden army ceases its attack.

The film concludes with Hellboy, Liz, Abe and Johann Krauss emerging from the stone giant, where Manning and other BPRD agents have been seeking entry into Bethmoora. Finished with the bureau, the four paranormal agents announce their intention to quit the agency, and then walk off into the sunset. A final moment in which Liz confesses that she is pregnant with twins fuels speculation for a sequel that would continue the Hellboy saga.

The paranormal characters of a third film would be conceived as were their predecessors — in Guillermo Del Toro's little leather notebooks, the source of inspiration for creature and visual effects teams striving to do their finest work. "In this movie," concluded Mike Elizalde, "we had Wink, the chamberlain, the Angel of Death, the fragglewump — one amazing character after another. The hit parade just kept coming. We owe a great deal of that to Guillermo's vision and to his creative nature. He allowed us to be creative in turn, and that was very rewarding."

Hellboy II: The Golden Army photographs copyright © 2008 by Universal Pictures. All rights reserved. Additional photos courtesy of Spectral Motion and DDT Efectos Especiales. Special thanks to Aisling O'Brien, Robin Hatcher and Bette Einbinder.



The film climaxes with a fierce battle between the BPRD agents and Prince Nuada's activated golden army soldiers. Double Negative reworked initial designs produced at Spectral Motion to arrive at an imposing robotic soldier with moving gears and cogs. Double Negative then created the entire golden army digitally, animating individual mechanisms through a procedural approach that linked gear movements to the motion of the soldiers' limbs. The animation rig also allowed animators to keyframe additional mechanical articulation on top of the procedural animation.

Batman Grounded

ARTICLE BY JODY DUNCAN



**Batman
Grounded**
ARTICLE BY JODY DUNCAN

In 2005, writer/director Christopher Nolan re-imagined, on film, the psychological and circumstantial origins of Batman, the dark and troubled crime-fighter created by artist Bob Kane and writer Bill Finger and introduced in Detective Comics in 1939. Batman's long run in the comic book realm spawned television series, animated and live-action, plus a quartet of feature films produced between 1989 and 1997 — the first two directed by Tim Burton, the last two by Joel Schumacher. With so many feet of film committed to his story, Batman, as source material, would seem to have been tapped out; but the character's many facets and an audience with an unquenchable bat-thirst made Nolan's *Batman Begins* a huge success.

Whereas the previous Batman features had been highly stylized and even whimsical in look and tone, Nolan had brought a more hip, relevant and grounded take on the character and his story. Portrayed by Christian Bale, this was a Batman who fought dangerous, down-and-dirty criminals — not cartoonish antagonists camping it up in inexplicable costumes. Nolan expanded on that philosophy in *The Dark Knight*, the much-anticipated sequel to *Batman Begins*, in which Batman faces off against Gotham crime bosses and the Joker, a madman in clown makeup intent on unmasking the mysterious vigilante. In keeping with the film's gritty, dark tone, the portrayal of the Joker by the late Heath Ledger is a portrait of painful, real-world psychosis that bears no resemblance to the grinning, debonair villain played by Jack Nicholson in the original *Batman*.

'Grounded' also described Nolan's methodology for making the film. As he did for *Batman Begins*, the director captured everything possible for *The Dark Knight* in camera, and turned to visual effects only as a last resort. "Visual effects are never Chris' first-choice answer to any problem," said visual effects supervisor Nick Davis, who, with visual effects producer Joyce Cox, shepherded 642 effects shots through three key vendors — Double Negative, Framestore and BUF Compagnie — plus a handful of support vendors. "He only goes to visual effects when he has exhausted every other avenue."

Nonetheless, visual effects would play a significant role in realizing on film the screenplay by Nolan and his brother Jonathan, based on a story by David S. Goyer. Picking up some time after the end of *Batman Begins* — which saw lunatics in an insane asylum released to the streets of Gotham City, and Bruce Wayne's ancestral home, Wayne Manor, burned to the ground — *The Dark Knight* has Batman grappling with the criminal element even as Bruce Wayne struggles with the internal conflict of watching his one-time love, Rachel Dawes (Maggie Gyllenhaal), prepare to marry district attorney Harvey Dent (Aaron Eckhart).

Though the production was based in London and all of the postproduction visual effects work would be done there, Nolan seated the film firmly in the real world by shooting much of it on location in Chicago. "On *Batman Begins*, we did about a month of location shooting in Chicago to establish Gotham City," noted Double Negative visual effects supervisor Paul Franklin, a key

contributor to the first film and the sequel, “but the majority of the work for the streets of Gotham and the interiors was shot on very large soundstages in the United Kingdom. This time, Chris was determined to get as much as possible on location in Chicago — exteriors and interiors — and so we had a full three months’ location shoot there.”

Nolan and director of photography Wally Pfister opted to punch up the veracity of location footage and other scenes by shooting a full 40 minutes of the film in native IMAX, the large-frame film format once reserved mostly for documenting the natural world in all its epic, awe-inspiring glory. “I think that shooting IMAX was Chris’ kick-back against the entire world going digital,” Nick Davis observed. “In his book, we’re losing a lot of the mystique and the glamour of film. In contrast to digital is this fantastic, beautiful IMAX format; and I think Chris just wanted to have a chance to show the public and the industry what we might be losing.”

Rather than look for ‘formula’ IMAX shots — wide-lens views, with slow, helicopter camera moves — Nolan and Pfister shot the IMAX sequences traditionally, mounting the large cameras on Steadicams and dollies, and even using them for handheld shots. “In terms of lenses and camera moves,” remarked Davis, “the only difference between the IMAX sequences and the rest of the movie was that we replaced 35mm cameras with IMAX cameras. Of course, that’s a big difference for production because those cameras are quite big and heavy! There is nothing easy about shooting IMAX, and we had a small army of technicians to keep them running and out of trouble; but it all went relatively smoothly. The most difficult part of the process was viewing IMAX dailies, because there are only a handful of theaters that can project them; and so, to watch your dailies, you have to get up at the crack of dawn and go to the theater before it starts running its regular show. Heaven help you if you want to watch a shot twice! There are also only a couple of labs that can deal with it, and only a few places that can record it out and scan it; but we were able to overcome all those hardships and develop a good methodology.”

In addition to a smattering of expansive IMAX establishing shots, *The Dark Knight* would boast five sequences that were fully IMAX from beginning to end. Of those five, three would involve extensive visual effects work. From the time he opted to use the format, Nolan’s primary concern had been image-degradation in the 214 IMAX visual effects shots; and so, prior to production, Davis and the teams at Double Negative and Framestore conducted a series of resolution tests. “An IMAX frame is something like 15K resolution,” said Davis, “which just doesn’t exist for a visual effects shot at this moment. The largest resolution we could handle in visual effects was 8K; but for most of the shots, even that was impractical, due to the amount of rendering time it would have taken and the disk storage space required. From our testing, we determined where we really needed to see the



In The Dark Knight – director Christopher Nolan’s sequel to his Batman Begins – Batman (Christian Bale) faces off against the Joker (Heath Ledger), a maimed madman who gleefully terrorizes Gotham’s citizens to force the caped crusader into revealing his true identity. Though Nolan’s approach to the film was to capture as much in-camera action as possible – much of it in IMAX format – the director relied on visual effects to augment locations shot in Chicago, to achieve dramatic stunt sequences, and to realize a central villainous character. Visual effects supervisor Nick Davis shepherded 700 shots through key

resolution — and we did those shots in 8K. Otherwise, we worked in 5.6K, which is essentially 6K, but adjusted to fit the film aspect ratio. If it was a fast-moving cut or something in low light levels, we could do the shots 4K, and they worked perfectly.”

effects houses Double Negative, Framestore and BUF Compagnie, plus several support vendors developed by Framestore to depict Two-Face’ Harvey Dent (Aaron Eckhart), who transforms from handsome, crusading district attorney – Gotham’s ‘white knight,’ and Batman’s best hope for hanging up his bat cape and mask – to disfigured vigilante killer when half his face is horribly burned in a Joker-orchestrated building explosion. Framestore created 120 Two-Face shots for the production.

One of the film’s all-IMAX sequences is a bank heist prologue that serves to introduce the Joker and his clown-garbed gang. Production shot live-action for the sequence in Chicago, using the old Chicago Post Office building as a stand-in for Gotham National Bank. Double Negative, which was assigned the effects for the sequence, completed its shots in October 2007 — a full nine months prior to the film’s release — to accommodate the studio’s plan to screen a five-minute, self-contained Dark Knight mini-movie in front of the IMAX release of I Am Legend. “Because this had to be delivered so early,” said Paul Franklin, “this was the first sequence where we figured out how to deal with IMAX. Even at 5.6K, we had to increase our storage capacity to handle all the data, and we had to completely retool our pipeline. When you get to these kinds of resolutions, all of the commercially available 3D rendering and compositing pipelines break down. So R&D lead Jeff Clifford and 2D supervisor Andy Lockley built a new 64-bit compositing pipeline, which allowed us to hold and manipulate these frames without crashing the computer. We did a major infrastructure upgrade for network speed, and we added processors on the render farm. On Batman Begins, we ran a render farm with 200 RenderMan licenses — 200 render nodes. For The Dark Knight, we expanded that to 900 render nodes, and each of those nodes ran a multiple processor; so it was actually equivalent to several thousand render licenses.”



Among Double Negative’s shots were those establishing Gotham City and key structures such as the Wayne Enterprises building. Working with aerial footage of an actual Chicago highrise, Double Negative executed a precise matchmove of the plate imagery and tracked the Wayne logo to the building. Double Negative also extended the city in the background, adding several hundred digital buildings, all individually textured and lit. As a final touch, Double Negative added to the shot the monorail system from Batman Begins snaking between buildings.

Double Negative used a shot near the end of the bank heist sequence — in which a member of Joker’s gang is hit by a school bus crashing through the bank doors — to iron out the wrinkles in its new pipelines. Nolan had attempted to get the shot entirely in camera, with stunt crews driving a real bus through the set and doing a wire-pull gag on a stunt performer to yank him out of harm’s way. Double Negative did cleanup work on the shot, and also retimed the action. “For safety reasons, they had done the wire-pull a considerable amount of time before the bus actually came through the doors,” said Franklin. “So, in the final plates, it was pretty obvious that the bus wasn’t hitting him. The stunt guy had reacted a bit too late to the bus coming through the doors, too, so we replaced his head and made it turn earlier. We also cleaned up the wire rig, and added an extra wave of 3D animated debris — rubble and bits of wood — as the bus backed in. It wasn’t a

spectacular shot, but it was very important to us because it was our first fully IMAX shot involving extensive CGI. We did a lot of R&D work on that shot.”

A 600-frame, fully 8K-resolution IMAX shot in the bank heist sequence has Batman standing atop a tower, looking out over Gotham. Again, Nolan had shot the image in camera, with Christian Bale standing at the edge of the Sears Tower, overlooking Chicago. Double Negative removed Bale’s safety rig and did a lot of cleanup work on the plate, removing dust and repairing negative damage — all at 8K. “That one shot ran to over two terabytes of data,” said Franklin, “which was considerably more data than everything we’d created for the 150 shots in our first feature film, *Pitch Black*, back in 1999!”

Following the prologue is another all-IMAX scene, the visual effects for which were executed under the guidance of Framestore visual effects supervisor Tim Webber, CG supervisor Ben White and compositing supervisor Jonathan Fawkner, the trio that spearheaded all of Framestore’s work in the film. The action is set in Hong Kong, where Batman — wearing a newly designed batsuit — arrives to capture a money launderer named Lau (Chin Han). Unlike the essentially one-piece rubber wet suit Batman sported in the first film, the redesigned bat suit was made up of multiple pieces of breathable materials, and therefore was more flexible, cooler and lighter weight, all of which combined to ease the discomfort of Christian Bale’s long hours in the costume.

From atop a skyscraper, Batman fires sticky-bombs at an adjacent building — Lau’s headquarters — and then, his batwing cape extended, glides across and smashes through a window into Lau’s offices. Production shot IMAX helicopter plates in Hong Kong, which Framestore augmented with CG buildings, incorporated into real plates for some shots and into all-CG environments for others. All of Framestore’s Hong Kong exteriors were created at IMAX resolution. “There are some quite closeup IMAX-resolution shots of the buildings,” said Tim Webber, “so we had to do very intense work on those shots, down to detailing the offices inside the building. IMAX isn’t just a matter of working on a larger image — you actually see stuff that you wouldn’t see in a normal shot. We had to detail everything to a much higher level.”

Shots of Batman in flight between buildings used a digital double modeled by Double Negative and then handed over to Framestore, which executed its own animation rigging and texture work. Double Negative had created a CG Batman for *Batman Begins*; but the redesign of the bat suit required an all-new model for *The Dark Knight*. “The only part of the Batman model from the last movie that we were able to reuse for this one was the cape,” noted Paul Franklin, “because that was the only part of the costume that didn’t change. We did a new cyberscan of Christian Bale in full costume and modeled the new suit, which was a much more complicated design than the old one, and therefore much more complicated to build. The original had little detail because it was basically



Production shot Chicago's Hotel 71 to represent the exterior of the structure housing Bruce Wayne's penthouse apartment, while production designer Nathan Crowley dressed the lobby of the Illinois Plaza building to stand in for penthouse interiors. After determining that Hotel 71 was not large enough to accommodate the penthouse floor plan, Double Negative created a re-proportioned version of the high-rise, placed it over the real building in the plate, and added the penthouse to the top floor.

a rubber skin. The new one looked much more like American football armor, made up of many different pieces and materials. Our shading team, led by Philippe Leprince, worked very hard to replicate all of those materials in the costume.”

Inside the office building, Batman engages Lau’s men in hand-to-hand combat. The fight scene was shot on a set, with greenscreen covering the window areas. Framestore then tracked in views of Hong Kong assembled from CG and plate elements. Cornered, Batman grabs Lau and detonates the bombs to blow out the entire corner of the building. New Deal Studios built and shot a partial building miniature for the exterior view of the explosion, matching it to an interior view filmed on the full-scale office set. “They’d already shot this interior view with the windows blowing out,” stated New Deal supervisor Ian Hunter. “We built a matching, 16-foot-square, quarter-scale section of three floors of the building, with a window made of breakaway materials. We also built a rudimentary interior so that when the glass face blew off you’d see some interior detail.” New Deal construction lead Forest Fischer supervised the miniature build.

For filming, which took place at night, New Deal mounted the miniature atop an industrial scissor-lift in a parking lot at Downey Studios, then raised it to a height of 20 feet. “This was supposed to be a skyscraper,” noted Hunter, “so it had to be high enough that the glass would fall away from the building and not just hit the ground. We surrounded the miniature in black and then shot it with a Technocrane so we could do a swinging move on it that looked like a helicopter move.”

Pyrotechnician Richard Helmer rigged the explosion and the large fireball that blows out of the shattered glass building. Framestore tracked the miniature element into its CG version of the building, and then surrounded it with a composite environment kluged together from Hong Kong plate elements.

Batman lashes himself to Lau and fires his grappling gun, jettisoning an inflatable balloon that carries the pair upward. A hook-equipped C-130 plane then flies in low and plucks Batman and Lau from the sky. Framestore built a CG C-130 for the shot. “We also shot a real C-130 flying in Hong Kong,” Nick Davis observed, “but there were limitations as to where we could fly; and so we needed the CG plane for some shots. We also did incredibly complicated, dangerous helicopter work to get IMAX plates for shots of the C-130 and Batman flying around buildings. It was only after we’d shot as much of the real plane and the real plates as we could that Chris Nolan said, ‘Okay, you can start building things in CG now.’ Framestore started building pieces of Hong Kong in CG, and the CG plane, and then they put it all together.” The extraction shot also featured Framestore’s CG stunt doubles for Batman and Lau.

Nolan added an IMAX closeup to Framestore’s slate of shots in the sequence just a few weeks before delivery. “They had a plate of a police officer standing in the office with the side of it blown out,” noted Tim Webber, “just looking out this hole, after Batman has been extracted from the building. It was a plate looking back at him, with just a little bit of the exploded wall visible at the edge of frame. Chris Nolan wanted it to be changed into a much wider shot, where you would see much more of the building and the surrounding offices. It was difficult because the original shot hadn’t been intended as an effects shot. On top of that, it was an IMAX shot, and quite close up on the CG building — much closer than we’d ever expected to be.”

The action returns to Gotham, and to Bruce Wayne's luxury penthouse suite, which has replaced Wayne Manor as Batman's base of operations. Production used two Chicago skyscrapers to represent the interior and exterior of the Wayne penthouse building. The penthouse interior was actually the lobby of the Illinois Plaza building, one of a cluster of modernist skyscrapers located south of the Chicago River, designed by architect Mies van der Rohe. Production designer Nathan Crowley dressed the Illinois Plaza lobby to resemble a swank penthouse suite; but its placement on the ground floor mandated Double Negative visual effects to achieve appropriate views out the large picture windows. "To allow us to put in higher views," said Paul Franklin, "we covered most of the windows with greenscreen — but not all of them. Chris wanted to keep greenscreen down to an absolute minimum, because he didn't want green spill to affect the way they were lighting the scenes. If you put greenscreens at the windows, you can't light through them — and there were quite a few daylight scenes, which required exterior light to come in. We had greenscreens for only about half of the shots inside the Wayne penthouse. For the rest of them, we had to do a lot of painstaking rotoscope work to separate everything out and put in new backgrounds."



An early sequence, shot entirely in IMAX, has Batman flying to Hong Kong to capture Lau (Chin Han), a criminal who is laundering organized-crime money. Production shot IMAX helicopter plates in Hong Kong, which Framestore augmented with CG buildings. The high resolution of the IMAX shots required that Framestore detail its CG structures to a very high level. Shots of Batman in flight between Hong Kong skyscrapers used a digital double modeled by Double Negative and then handed over to Framestore for animation rigging and texturing.

Double Negative created the expansive views of Gotham as digital matte paintings, working primarily from location photography. “We did a very extensive location still shoot,” observed Franklin, “much like we had done on *Batman Begins*. We thought we’d shot everything it was possible to shoot in Chicago for that film, but Chris was very keen not to repeat himself; and so, we had to go out and capture images from parts of Chicago we hadn’t seen before. This time, we had a lot of enhanced tools at our disposal, such as the high-resolution Canon 1DS MkII digital SLR camera, which greatly improved the quality of the images we captured.”

Chicago’s Hotel 71 — an austere-looking glass-and-steel skyscraper with deep blue-tinted windows — stood in for the exterior of the penthouse building. The plan was to replace Hotel 71’s top floor with a CG construct based on the Illinois Plaza lobby. “We were going to just plop this CG penthouse-floor model on top of the live-action building,” said Franklin, “but we quickly realized that the floor plan of Bruce Wayne’s penthouse was twice the size of the floor plan of Hotel 71! So, to make the penthouse fit on top, digital architecture lead Jordan Kirk built an enlarged version of Hotel 71 in CG. Chicagoans will recognize the building, because it is very distinctive; but we completely changed the size and proportions to accommodate the Wayne penthouse on top. Lead compositor Bridget Taylor then placed that into an IMAX helicopter plate of Chicago, shot at magic hour, in this wonderful dusk light.”

The penthouse is the setting of a political fundraiser Bruce Wayne hosts for Harvey Dent. When the Joker and his gang crash the party, Wayne quickly ducks out, and then re-emerges as Batman. A fight ends with the Joker pushing Rachel Dawes — soon to be married to Dent — out the penthouse window. Batman leaps out the window after her, catches her, and then uses one of his extended bat wings to spiral downward, finally crash-landing on the roof of a taxi.

Nolan shot most of the fall sequence practically, on a partial exterior penthouse set built at Cardington Studios, where the director had shot much of *Batman Begins*. On the set, surrounded with greenscreen, production shot stunt performers falling a distance of 100 feet on a wire descender rig. Ultimately, due to excessive greenscreen reflection in the live-action footage, Double



After apprehending Lau inside his headquarters, Batman uses sticky bombs to blow out a corner of the building and make his escape. For exterior views of the blast, New Deal Studios built and shot a partial building miniature, matching it to an interior explosion shot filmed on a full-scale office set.



New Deal’s quarter-scale miniature featured windows made of breakaway materials and rudimentary interior dressing. Crew members mounted the miniature atop an industrial scissor-lift in a parking lot at Downey Studios, and then raised it to a height of 20 feet for filming so that glass shattered in the explosion would fall away realistically.

Negative lead compositor Robin Beard replaced the set with a synthetic environment created by environment lead Dan Neal. “They kept only Batman and Rachel as live-action elements,” said Paul Franklin, “and then we added in the buildings rushing behind them. The view when they first fall over the edge of the roof — a skyscraper canyon 110 stories below — was fully CG, as well.” Two shots employed digital doubles: one in which Batman first extends his bat wing, and a final shot just before he and Rachel strike the taxi. “The special effects and stunt crews had done a wonderful job with the cape and wire rigs, but they couldn’t really get the cape to extend properly and start Batman’s spiraling movement. The kind of energy and speed they needed out of it could only be achieved with a digital stunt double. But the live stunt reference really helped because it showed us how they should be moving, and how the cape should react.”

The disrupted fundraiser is not the last Batman and Gotham citizens see of the Joker, who next launches a series of bomb attacks throughout the city to coerce Batman into revealing his true identity. To stop the Joker’s terrorism, Harvey Dent publicly claims to be Batman — and is promptly arrested by Gotham police for vigilante crimes. As the police transport Dent via armored car, the Joker in an 18-wheeler semi-truck and his minions in a commandeered garbage truck give chase, forcing the police convoy into Gotham’s underground freeway system. Soon, Batman enters the high-speed pursuit in his ‘tumbler’ batmobile. Though the sequence would feature a lot of visual effects work by Double Negative, Nolan shot most of the mayhem practically on Lower Wacker Drive in Chicago, with special effects supervisor Chris Corbould flipping cars and setting off full-scale pyrotechnics. The sequence also made use of four practical batmobiles that Corbould’s team had built for *Batman Begins* and refurbished for *The Dark Knight*. “We did some small modifications to the cars,” said Corbould, “just to iron out a few glitches. The biggest thing we did was put in air conditioning for the driver, because it got bloody hot in there.”

To stop the garbage truck, Batman rams it head-on, digs underneath it, slams it up into the ceiling of the underground freeway, and then does a 180-degree skid and takes off in the opposite direction, after the Joker in the semi-truck. New Deal Studios executed the tumbler/garbage truck encounter as a 1/3-scale miniature effect. At 1/3 scale, the tumbler measured about five-and-a-half feet long, while the miniature garbage truck extended to nine and a half feet. Rather than construct the scale batmobile from scratch, New Deal modelmakers, led by Forest Fischer and mechanical supervisor Scott Beverly, refurbished the same-scaled radio-controlled car that Cutting Edge had built for *Batman Begins*. “We replaced all the electronics and lights in it,” explained Ian Hunter, “and also beefed up the steering so that the batmobile could do this 180-degree spin-out at the end of the scene.”



New Deal also built the tumbler for Batman's chase sequence in which he crashes into the Joker's vehicle. The stunt was duplicated for the movie's action sequences, including a garbage truck. New Deal built the trash vehicle as a 1/3-scale model for a shot in which Batman crashes into it with his batmobile 'tumbler' vehicle, disabling it and ramming it into the ceiling of an underground freeway.

New Deal built a stunt version of the tumbler from scratch. "We didn't want to destroy the high-end car," said Hunter, "so we built this stunt version to ram into the garbage truck. The stunt tumbler was essentially the same size and shape, and it had all the same working lights and radio-controlled steering. The only difference was that it was not a self-contained, remote-controlled vehicle. Instead, it was attached to a steel skate that we could pull with a cable from below the set. It was also connected to a horizontal bar that had pivots on it, so we could steer the car and get some side-to-side motion as it was being pulled to give it a little extra life."

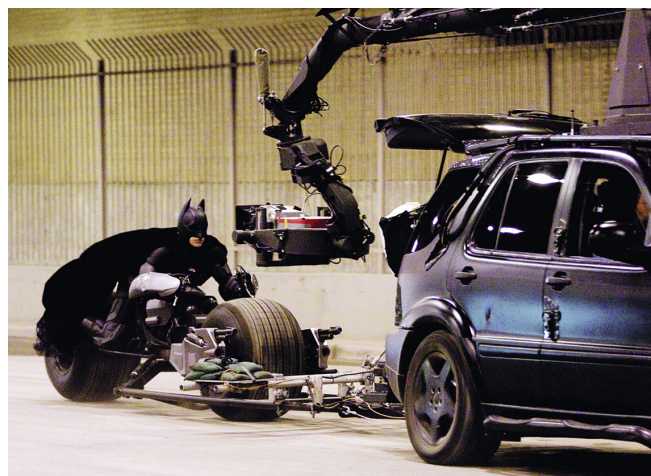
Modelers built a steel chassis into the stunt tumbler to ensure it would withstand repeated ramming into the larger garbage truck. "It had a fiberglass shell, but below that we built a 3/8-inch steel front end that allowed us to lift the garbage truck and ram it into the roof of the set." New Deal also equipped the tumbler's below-deck skate mechanism with a shock-absorbing ram, which pushed against the garbage truck model when the two vehicles collided and absorbed most of the force.

In contrast to the sturdy stunt tumbler, the garbage truck model was made out of lightweight materials. "In reality, because its mass was greater, the garbage truck should have stopped the batmobile," Hunter noted, "but Chris didn't want the batmobile to stop — he wanted it to hit the truck and keep going. So we went for really light materials on the garbage truck, casting the body of it out of resin and aluminum foil."

To stage the action with the vehicles, New Deal built a scaled section of the Lower Wacker location — approximately 120 feet of dressed set, plus 60 feet



A high-tech motorcycle, the 'batpod,' emerges from the tumbler when it is totaled in the chase. Special effects supervisor Chris Corbould and his crew built four practical batpods for in-camera shots. Designed for aesthetic appeal rather than maneuverability, the difficult-to-handle batpod was driven by stunt driver Jean Pierre Goy, who stood in as Batman in nearly all of the live-action shots.



Corbould also supplied a camera rig that enabled production to shoot closeups of actor Christian Bale aboard the batpod.

of undressed ramp-up space used to get the batmobile up to full speed as it traveled toward the garbage truck. After Hunter had photographed the Chicago location extensively, New Deal built a 3D computer model of Lower Wacker Drive, and presented that to Nick Davis for approval. Davis requested that the tunnel ceiling be lowered, so that more damage would be inflicted on the garbage truck when it was slammed into it. New Deal computer modelers cheated the ceiling down in the 3D model; and then that model was used to build the actual miniature set. New Deal extended the miniature with a large translight generated from location photographs.

Davis, Hunter and New Deal director of photography Tim Angulo shot the tumbler/garbage truck collision on stage at Downey Studios, where the set had been mounted to scaffolding to allow the crew below-deck access. Servomotors powered the cable-driven vehicles. “The batmobile and the garbage truck were driven towards each other,” explained Hunter, “and then, about 10 feet before they hit, we released the garbage truck from the cable, so it was just freewheeling down the set.” The miniature setup also included two cable-driven camera cars, one built by New Deal and one built by a team from Spydercam. “The one we built was based on a go-cart chassis, and it had a boom and swing head on it. This car was used for shots following behind the batmobile. Spydercam’s rig, which was used for shots alongside the tumbler and rode to the side of the set, also had swing and boom capabilities. On the ends of those we put Libra heads, which gave us our pan and tilt.” The camera rigs were operated through a motion control system. “First, Tim Angulo would run all the vehicles through the set at half speed and program the pan and tilt on the cameras, with Tim Drnec of Spydercam programming the dolly part of it. Once Nick Davis was happy with that move, we would ramp it up to shooting speed, which was 48 frames per second. Rather than try to follow this fast action by eye, we could play it back at the operating speed without missing anything.”

The miniature photography crew broke down the action — as illustrated in previz generated by Nvizage — into three separate events: the first would have the batmobile crashing into the garbage truck, lifting it upward and ramming it into the top of the tunnel set; the second would have the batmobile pushing the garbage truck the length of the tunnel; the third action would be the batmobile’s disconnecting from the garbage truck, spinning 180 degrees, and speeding off. “I thought it would be impossible to get all of those things to happen in one take,” Hunter said, “so we scheduled ten days for the shoot, allowing time for resets and alternate camera positions for each of the three setups. On the first day, on our first take, we drove the batmobile down the set with the cameras behind it, and we drove the garbage truck towards it — and as soon as they hit, the batmobile picked up the garbage truck, smashed it against the roof, kept going down the full length of the set, stopped, and shoved the garbage truck off the end. The garbage truck then uprighted and



A Gotham City Police helicopter joins the chase. Double Negative produced all-CG high-angle shots of the helicopter in flight, reconstructing Chicago's LaSalle Street location from extensive lidar and phototexture surveys. Double Negative developed a procedural traffic system, complete with changing stoplights, and lit the model to match the cinematography of the real boulevard. Built to hold up at IMAX resolution, the CG chopper featured CG SWAT team members and pilot.

slid on its wheels all the way to the back of the set, where it finally came to a crashing halt with all of this trash and debris falling behind it. All of that happened in one take. It wasn't exactly what was in the previz; but when we showed it to Chris Nolan the next day, he said: 'Hey, that's pretty good — I don't need to cut away from this. I might just use this the way it is.' We all looked at one another, wondering what we were going to do with ourselves for the next nine days!" To complete the sequence, New Deal did spend some additional hours shooting the spin-out maneuver with the radio-controlled batmobile, driven by mechanical technician Jon Warren.



Batman ensnares the semi-truck driven by the Joker with cables, causing it to flip end over end – an audacious practical effect achieved by Chris Corbould's team in the heart of Chicago's banking district.

Double Negative compositor Graham Page cleaned up the miniature photography, removing tracks in the set, and also did extensive grading work to match the lighting to the real location. “We did a bit of set extension, as well,” said Paul Franklin, “adding in a view of the Chicago River. We even added the Joker’s semi-truck going in the opposite direction as the batmobile zooms past it. We just took that from a plate and put it into the miniature shot.”

After disabling the garbage truck, Batman sets off at full speed after the Joker, who is firing rocket-propelled grenades from the semi and is about to take out the armored car. Batman engages the batmobile’s rocket-booster, which sends the car flying between the semi and the armored vehicle, intercepting the RPG. On location, Chris Corbould launched the full-scale tumbler off the back of a ramp, detonating pyrotechnics to blow off the vehicle’s back wheels as the RPG strikes. Double Negative removed the ramp and the car that was pulling it. A subsequent shot of the batmobile crashing to the ground and through barriers was also shot practically and full-scale — but on stage at Cardington, where the production had built a full-size section of Lower Wacker specifically for special effects gags.

Having sustained considerable damage in the RPG attack, the batmobile shudders to a halt. Batman then activates an ‘ejection sequence,’ which causes the car to lurch as its front wheels spin furiously. For shots of the batmobile in its death throes, Double Negative senior modeler James Guy — who had built a digital batmobile seen only in long shots for *Batman Begins* — rebuilt the model to stand up in IMAX resolution. “There were shots of our digital batmobile sitting there, full frame, in brightly lit conditions, and in a trashed state, all covered in mud and dirt,” noted Paul Franklin. “We did an extensive digital texture shoot of the full-size car in the U.K. to accurately match all the dirt textures. Lead animator Dorian Knapp produced animation of the car spinning its wheels and lurching about, and TD Nicola Hoyle used a lot of physics software, including our own proprietary dnDynamite software, to create the shuddering and shaking of the batmobile panels.”



The special effects crew spent a month building the largest nitrogen cannon Corbould had ever employed, tested it in a desolate area, and then executed the gag on one of only two 50-foot stretches of LaSalle Street solid enough to withstand the 120 tons of pressure exerted by the cannon. Double Negative did extensive cleanup work on the shot, removing rigs and replacing portions of the street that revealed rig shadows.



The extent of Harvey Dent's burn injuries is fully revealed in a hospital scene. After finessing the Two-Face design to ensure the look was horrific but not overly gruesome, Framestore modeled the 3D burned-Dent face in Maya, tweaked it in Mudbox, and then animated it to match Aaron Eckhart's performance in the liveaction plate. Animators employed procedural animation tools that articulated the exposed muscles and bones of the CG side to conform with the movement of the actor's face.



The visual effects team typically set up three video witness cameras on set to capture Eckhart's facial performance from a variety of angles. The crew used small, lightweight, portable and entirely self-contained HD cameras to curtail interference with the main unit and ensure accessibility even in tight spaces.

A high-tech motorcycle, the 'batpod,' is born when the tumbler's panels blow off and its wheels begin to realign. "Chris Nolan wanted very specific actions in the birth of the batpod," said Nick Davis. "He wanted the front two tires of the tumbler to do this very complicated maneuver, moving hydraulically across each other and locking into a new position, one in front and one in back. Meanwhile, Batman would be ejected out of the vehicle, attached to a gyroscopic seat that would become the center of the batpod bike. Through this series of actions, the tumbler would become this futuristic, skeletal bike thing."

True to form, Chris Nolan wanted to attempt the transformation of the batmobile into the batpod as a practical effect — and Chris Corbould

enthusiastically took up the challenge. "I was very

keen to do that practically," admitted Corbould. "We came up with a fairly complicated mechanical rig that moved one wheel of the batmobile so that it became the back wheel of the batpod. Another mechanism made the batpod handlebars rise up." What the practical rig could not achieve was the effect of the batpod becoming airborne as it literally exploded from the batmobile interior, as illustrated in the previz. "That would have been very difficult to do for real. In the end, even I realized that we were compromising the shot just to do it practically."

"The practical rig just couldn't give Chris Nolan the energy and momentum and impact he wanted out of the shot," added Nick Davis. "So that ended up being a completely CG shot by Double Negative — and completely IMAX, as well."

The brief from Davis and Nolan was that the transformation should not look at all fanciful or magical; rather, it had to have a logical mechanical basis. "They didn't want some sort of elaborate digital origami trick," said Paul Franklin, "so we came up with a lot of mechanical moves. Gun pods come out the front in a clunky, mechanical way, with a lot of jerking and shuddering, and there are hydraulic mechanisms and rams and pistons moving around." Dynamics systems animated by Trina Roy contributed to a final shot of the batmobile jettisoning all of its panels in one big explosive moment. "They all blow off and go flying around, bouncing off the walls. Then you see the batpod, lit by Bruno Baron, lurch out from inside the batmobile and tear off down the road."

Though the batpod birth sequence featured a CG version of the bike, Chris Corbould's crew built four practical batpods for use throughout the film. Designed to look great rather than handle well, the batpod was difficult to maneuver; and so production hired stunt driver Jean Pierre Goy to stand in as Batman aboard the batpod in nearly all of the live-action shots. "Jean Pierre became absolutely committed to this bike," said Corbould. "The first time he rode it, within half an hour he was riding it standing up in the seat. He was phenomenal. Christian Bale had a go on it, too; but no one wanted to take the risk of putting him on it too much. So we made special rigs that allowed us to get really good close shots of him speeding along."



Eckhart wore tracking markers as he performed his Two-Face scenes to aid Framestore in tracking the animated Dent face to the actor. Tracking was one of the most critical aspects of the effect, as even slight slippage would be evident in closeups.

One of the safety concerns in filming shots of Batman on the batpod was that the character's long cape would get tangled in the bike's back wheel and cause injury. To test the cape's interaction with the batpod, the effects crew dressed Goy in full Batman costume, but attached the cape with special clips that would break away if the fabric became caught in the wheels. "Jean Pierre drove off," recalled Corbould, "the cape fluttering behind him — and it looked great. The wind underneath the cape lifted it in a beautiful way. It was so iconic-looking, Chris had to shoot it that way — and it was never a problem."

Even with Goy's expertise as a stunt driver, and with his commitment to mastering the bike, there were severe limitations to what the practical batpod could do. "The practical batpod was great at going 70 miles per hour in a straight line, blasting through intersections," said Nick Davis, "but it didn't turn very well. It also couldn't do all these incredible things Chris Nolan wanted to see — like the bike skidding sideways, or flattening very low to the ground, or climbing straight up a wall and then doing a 180-degree turn. The only way to get all of that kind of batpod action was with a CG version. Double Negative did fantastic work on that, and they were able to make the batpod do all kinds of things we could never have done practically."



As part of an extortion plot to unmask Batman, the Joker terrorizes Gotham's citizens by detonating structures throughout the city, including Gotham General Hospital. Production arranged to shoot the controlled demolition of a derelict five-story building in Chicago for an IMAX in-camera shot of the Joker exiting the hospital as the building explodes behind him. Chris Corbould supplied pyro enhancements to the demolition, and Framestore sweetened the in-camera shot, adding digital debris and shattering glass windows.

While Batman gives chase on his batpod, the Joker's gang fires steel cable across a street — shot on Chicago's LaSalle Street — forming a lattice-work that snares a low-flying police helicopter and causes it to spin out of control, crash into a building, and tumble down the street towards the approaching armored car carrying Harvey Dent. The armored car clips the side of the burning helicopter, which then spins off and explodes in a corner of the street. The fiery helicopter crash was achieved through digital effects animated by Mike Nixon and composited by Gruff Owen and his team. "The shot where we establish the chopper flying down the street was real," observed Paul Franklin. "Stunt fliers flew the chopper below rooftop level, right down the middle of LaSalle Street — which is only about 80 feet across, so it was pretty dangerous stunt flying. Then there was a series of digital shots of the chopper catching the wires and crash-ing into the building and the ground. We created a fully CGI helicopter and also a fully digital replica of the LaSalle Street environment — lit by Pietro Ponti and Zoe Cranley — all of which had to hold up at IMAX resolution."



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Batman lowers the batpod, drives beneath the moving semi, and comes out the other side, pulling a cable behind him. Double Negative's Stewart Ash animated the digital batpod for the shot, while CG supervisor David Vickery made the street-level digital environment. Batman then drives onto the pavement and whips around lampposts, weaving the cable and anchoring it into the ground with explosive bolts. The semi-truck pulls the cables taut as it continues moving at full speed, then pulls lampposts out of the ground — another all-CG shot. "Chris had shot part of this for real with Chris Corbould's team," said Franklin, "but he wanted a more dramatic sense of weight as the lampposts were pulled out of the ground, with the pavement ripping up and everything — so we re-created all of that in CGI, and Tilman Paulin composited it."

Remarkably, the practical effects team was able to accomplish the most dramatic and spectacular moment of the chase, in which the cable-entangled semi flips end over end. "Chris Nolan was quite passionate about doing this thing for real," said Chris Corbould, "right on LaSalle Street in Chicago. But I wasn't at all sure that we could do it. I kept suggesting ways to make it easier for us, such as flipping the back end of the truck only, rather than the whole thing. But Chris isn't very compromising on things like that. So, finally, I said: 'I'll make a deal with you. I'll build this rig and test it once; and if we're anywhere near doing it, we'll go for it. If we're not, then we'll have to do a model or CGI.' He said, 'Okay, deal.' So I got a couple of my specialists in flipping cars, and they set to work building the biggest nitrogen cannon I've ever seen. They rigged that over the course of a month; and then we went to a test site out in the middle of nowhere and set up our cameras. We set the truck running, turned on the tracking cameras inside of it, and when it got up to 22 miles an

hour we pressed the button and, much to our surprise, the whole thing flipped over. It was absolutely beautiful!”

Flipping a semi-truck in a desolate test area was quite a different proposition than flipping it in the middle of Chicago, however. “We were doing this right in the heart of the banking district,” noted Corbould, “with all these massive buildings on either side of the road. If the truck had deviated five or ten degrees, it would have gone straight through the window of one of these buildings.” Corbould discovered another problem with the location when he scouted LaSalle Street. “I’ve never seen so many manhole covers in all my life! We had it surveyed, and it turned out that all the banks have underground vaults there. There are vaults, services and all kinds of things under that street. To flip the semi-truck, the pistons on the cannon had to push down at a force of about 120 tons in one spot; so my nightmare was that we’d do this and suddenly there would be a great big hole in the ground and we’d be looking into a bank vault or something. There were only two 50-foot solid stretches of the street where we could even do this thing.”



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The crew set up cameras with remote heads quite close to the event, which Corbould’s crew executed just one time — flawlessly. “It was an amazing thing to see,” recalled Paul Franklin. “I watched this with Heath Ledger, who was dressed in his Joker costume, standing about 50 yards away from it, down a side alley. To see the rear end of the trailer come up and then slam down onto the street was quite an unusual experience. I thought to myself, ‘Well, this is it — Chris Nolan really does want to do everything for real!’” Double Negative added CG cables to the truck. Senior compositor Dan Snape also did extensive cleanup on the shot, removing the large ram that shot out the back and other rigs. “We had to digitally replace the road underneath it, as well, because there were shadows from the rigs that we just couldn’t get rid of.”

The sequence finishes with a final outlandish batpod maneuver as Batman rides the bike straight toward a wall, looking as if he is going to crash. Instead, he drives the batpod up the wall vertically, then pivots in the seat and drives it back down. “That was a fully digital shot, as well,” stated Franklin, “put together by lead compositor Ciaran Crowley. We had to create the cape animation of Batman through this moment, which has some pretty gravity-defying pivots. Our digital cape team, led by John Kilshaw, did the cloth dynamics of Batman’s cape. They did an incredible job of making the unbelievable look quite realistic.”

The Joker is captured and thrown in a cell at Gotham City Police Headquarters, where he informs Batman that he is holding Harvey Dent and Rachel Dawes captive at two different locations, timed bombs strapped to them. With only enough time to save one of them — Dent, Gotham’s new bright hope, or Rachel, his longtime love — Batman arrives at an address provided by the Joker and finds Dent there, half his face soaked in gasoline. As Batman drags Dent out of the building, it explodes around them — a repeat-pass motion control explosion shot separately at Cardington. Framestore composited the actors into the shot. “We had to fit Batman and Dent into the explosion and the flames,” said Tim Webber. “It was fairly traditional work, but quite laborious. We had to do some manipulation of the explosion, as well, because it didn’t quite work the way Christopher Nolan wanted.”



The Joker’s threats of escalating violence lead to the evacuation of Gotham, shown in a wide IMAX shot. Production filmed a helicopter plate for the scene, flying over the Chicago River and looking down on Wacker Drive where some 500 extras milled about. After digitally removing unwanted traffic and pedestrians, Double Negative populated the shot with thousands of people and vehicles. Artists matchmoved a CG model of the scene to the helicopter plate, used a proprietary tool to paint tracks in specific areas, and then populated those tracks with items from a library of 3D-animated people.

A second shot reveals one half of Dent’s face on fire. “It was very tricky to get that shot to look believable,” Webber commented, “because it was quite an unreal image. The idea is that only one half of his face gets damaged, and the other part of his face doesn’t get damaged at all — that was essential to the story. So it was very important that the flames be on only one side of his face and not move over to the other half. But that’s not what would happen in reality, and so it was a hard thing to sell.” Framestore tracked a combination of simulated fire and real flame elements to the thrashing character in the plate. “I always like to combine the CG work with real elements when I’m doing something like this. You can’t get the real elements to respond exactly as you want, so you need a bit of CG for control; but the real elements help in that they give you randomness that you can’t really get in CG.”

‘Two-Face’ Harvey Dent is next seen in the hospital, covered in bandages, the horrifically burned side of his face finally revealed as he speaks to Lieutenant James Gordon (Gary Oldman). Framestore created 120 digital Two-Face shots, each of them among the most impressive and startling effects in the film. “You couldn’t have done this effect with a makeup,” said Nick Davis, “because a burn makeup is additive. It doesn’t create the effect of something having been removed from the face. It also doesn’t create a completely unique character, which is what Chris wanted. So we decided to track in a CG face that could talk, emote and perform — and Framestore did absolutely fantastic, superlative work on that.”

Framestore look development lead Rob Allman extrapolated from the original comic book image of Two-Face. “We got a scan of Aaron Eckhart’s face,” said Tim Webber, “and then we started doing concept artwork, coming up with a look that was horrible, but not so horrible that it was revolting.” Once the filmmakers settled on a general look from that concept art, they commissioned a sculptor from the prosthetic makeup department to model and paint a 3D sculpt. “It was a very useful stage, to see it in three dimensions; and then we made a couple of variations on that.” The final design had charred skin in some areas, and others where the epidermis was burned away completely. “There are slightly wet subcutaneous surfaces, and sections of the face where you can see through to bones and muscles moving. You see a lot of exposed area around the eyeball, as well. It almost looks like one of those anatomical models, where elements have been stripped away so you can see through to different layers. But we didn’t make it anatomically correct. We took creative license and changed the positions of the muscles and bones and joints to make it more dramatic.”

Framestore modeled the 3D Dent face in Maya, tweaked it in Mudbox, then tracked it to live-action plates in which Aaron Eckhart had performed wearing tracking markers on one side of his face. “It was a type of performance capture,” said Webber, “but we couldn’t do traditional performance capture where you have a lot of special cameras around and a special stage set up just for that purpose. We had to capture a performance that was happening during the main-unit shoot; and so we had to develop a system that was non-intrusive to the shooting process.”

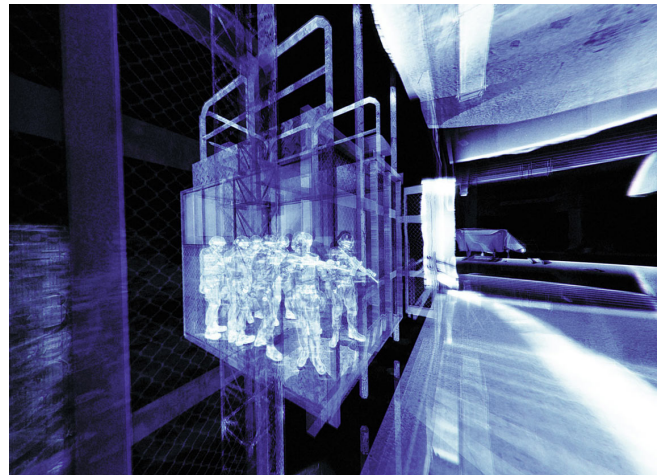
The visual effects team typically set up three video witness cameras on set to capture Eckhart’s facial performance from a variety of angles. “Usually,” commented Webber, “those cameras had to be set up in very little time; and so there was nothing particularly fancy about them. They were HD cameras, but 720P, the lower end of HD. They had to be very small, lightweight, portable and completely self-contained so we could get into a small corner of the set in five minutes, if we had to.” In addition to the tracking markers, Eckhart wore a burn prosthetic skullcap on his head, which Framestore ended up replacing in all but a few shots. “There are one or two glimpses of it where it was quite useful — we could just use the prosthetic as it was — but we ended up replacing it most of the time. However, it was still incredibly useful for lighting reference and for covering his hair, which had to be kept down anyway.”



Ferries transport evacuees out of the city. Double Negative built digital ferry models from photographs of New York’s Staten Island ferries, then composited them into a background plate shot at a Chicago pier. Double Negative also added CG water and boat wakes, extended docking gantries on the pier, and created the background city skyline as a matte painting. For ferry passengers, Double Negative used small greenscreen elements shot on high-def video.



With Wayne Enterprises CEO Lucius Fox (Morgan Freeman), Batman keeps tabs on Gotham's criminal element using a sophisticated console that employs sonar technology to generate three-dimensional images of the city's every quarter. BUF Compagnie created the effect for approximately 40 shots in the film, building constantly regenerating, 3D models of the city and integrating them into on-set monitors. BUF captured Nolan's vision of an all-seeing-eye effect that featured fluid camera moves and organic images with breakups and flares.



Batman uses sonar vision to conduct a remote search for the Joker throughout the city, ultimately finding the madman holed up in a partially constructed skyscraper, the Pruitt Building, where members of the SWAT team have been deployed. To create the sonar vision images, the visual effects crew conducted video motion capture sessions on the interior Pruitt Building set, recording SWAT performers re-creating actions immediately after they had been filmed by the main unit. The visual effects team also photographed textures and gathered lidar scans of the set to aid its re-creation in 3D.

Framestore used the capture data to re-create Eckhart's performance on the CG model, enhancing it where necessary via an animation system that had a significant procedural component. "We had quite complex techniques set up in the rig so that when the actor's face moved in certain ways, the muscles would respond accordingly, and the skin would slide in a particular way," said Webber. "It wasn't necessarily an exact copy of the actor's facial movement, but it looked logical. We had to really think through that — what would happen to this charred side of the face if the good side were doing this or that? That was all designed into the system, rather than being worked on individually and by hand." In some cases, Framestore tweaked the live-action performance of the good side of Dent's face, as well, to secure a better match up with the CG side.

With no margin for error, and no room for even a slight slippage — especially in the many closeups on Dent — tracking the animated face to the actor was the most critical, and most challenging aspect of the effect. "Our CG face had to join seamlessly with the real live-action," said Webber, "and it had to match the movement and performance of the real face perfectly — because the good side of the face was right there to make a direct comparison to. We partly used Movimiento, an off-the-shelf software from Realviz — now owned by Autodesk — that is specifically designed for tracking using multiple cameras. We also developed some in-house techniques for dealing with this very difficult tracking job."

Escaped from jail, the Joker continues to terror-ize Gotham, detonating structures throughout the city. For an in-camera shot of the Joker exiting Gotham's hospital while the building explodes behind him, production arranged for the demolition of a derelict building in Chicago. "We helped it a little bit with visual effects," said Nick Davis, "just to set in some windows and other bits and pieces; but on the whole, that was a practical building explosion, with Heath Ledger in front of it, all shot IMAX."

The Joker threatens to blow up Gotham's bridges and tunnels, which leads to a mass evacuation of the city, established in a very wide, 500-frame, 5.6K IMAX shot. Production shot a helicopter plate for the scene in which thousands of citizens flee Gotham, flying over the Chicago River, looking down on Wacker Drive, where approximately 500 extras milled about. "We kept those extras and the military vehicles they had on set," observed Paul Franklin, "but lead compositor George Zwier did a lot of digital paint work to remove traffic and other pedestrians that could be seen beyond the lockdown area. Then we had to populate the shots with about 50,000 people and 10,000 automobiles."

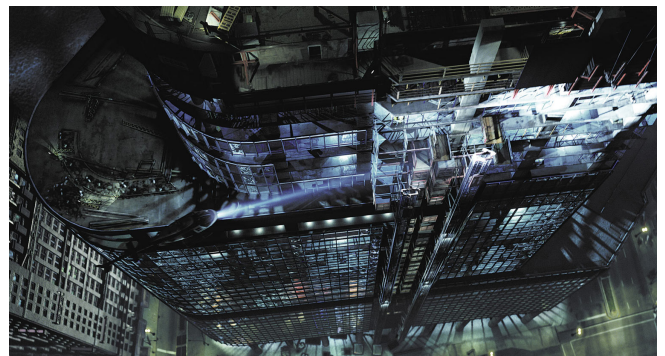


Batman uses sonar vision to conduct a remote search for the Joker throughout the city, ultimately finding the madman holed up in a partially constructed skyscraper, the Pruitt Building, where members of the SWAT team have been deployed. To create the sonar vision images, the visual effects crew conducted video motion capture sessions on the interior Pruitt Building set, recording SWAT performers re-creating actions immediately after they had been filmed by the main unit. The visual effects team also photographed textures and gathered lidar scans of the set to aid its re-creation in 3D.

To create the crowd, Double Negative looked at a variety of solutions, including Massive, but ultimately created its own crowd software. “We had some unusually specific requirements for this shot,” said Franklin, “and so rather than deal with a commercial or artificial intelligence solution, we elected to develop a new system — designed by Gia Sadhwani and Jon Stroud — which is basically a high-level art direction tool that allows you to paint tracks directly onto a CG model. We created a model of the whole evacuation scene and matchmoved it very precisely to the plate; and then we used this tool to paint in tracks of where we wanted people. We could then populate those tracks with items from a large library of 3D-animated people we’d assembled from footage of the actual extras on set in England and in Chicago, using them as rotoscope animation guides.” Double Negative artists referred to the program as a ‘dumb’ system, rather than an artificial intelligence system, because all of the intelligence remained in the head of the artist using it. “This system wasn’t going to do anything for us. It had some simple rules — it wouldn’t let people walk through cars, for example — but it didn’t create any kind of behavioral pattern. It gave us the ability to edit these thousands of little people walking around in the scene; but it was up to the artist to choreograph and direct them.”

Gotham evacuees make their way to the docks where they board departing ferries. Production had explored the possibility of shooting a decommissioned Staten Island Ferry located on Lake Michigan for the sequence; but the ferry’s dilapidated state made it unusable. Double Negative took on the assignment of creating the ferries digitally for wide shots, and extending a practical ferry stern section built by production for shots of people boarding the craft. Double Negative sent a team to Manhattan to document the Staten Island ferries there. “One of our two senior CG supervisors on the show, Peter Bebb, flew out to Manhattan, accompanied by people from Lidar VFX,” said Franklin. “Peter and the Lidar guys photographed every conceivable angle of the ferry in New York, and also shot extensive footage of the ferries maneuvering in the water.”

For a shot of two ferries leaving dockside and setting out on the water — one filled with Gotham citizens, the other with convicts evacuated from city jails — Double Negative senior compositor Sanju Travis composited digital ferries into a background plate shot at a Chicago pier. “We replaced all the water around the ferries,” observed Franklin, “because we wanted to create wake patterns, and it was easier to replace the water than to blend it in with the water in the plate. We did a lot of work to create wind patterns and undercurrents so the water would have the requisite level of detail to hold up at full resolution.” As orchestrated by the Joker, the electrical systems on both ferries fail, causing them to stall. Wide shots of the water-bound ferries, with the backdrop of the cityscape behind them, were all-CG, with CG ferries, fully digital water, and a CG view of Gotham City built out of a library of



Double Negative produced IMAX-resolution shots of the Pruitt Building, modeling the skyscraper from photographs and lidar data of the partially completed Chicago Trump Tower. The final CG Pruitt Building stood 70 stories tall and featured intricate construction-site detail, such as cement mixers, spools of wire, cranes and shipping containers. An establishing shot of SWAT officers rappelling down the skyscraper was all-CG, with digital building, SWAT team, street-level police activity, helicopter and surrounding city.

approximately 50 buildings Double Negative had photographed in Chicago. For the ferry passengers, Double Negative used small greenscreen elements shot on high-def digital video.

Learning that the Joker has placed bombs onboard the stalled ferries and is threatening to set them off, Batman uses a sonar 'eye' device, introduced earlier in the film, to conduct a remote search for the madman throughout the city. BUF Compagnie generated the sonar vision effect, building a constantly regenerating, three-dimensional model of the city. "BUF created all of the sonar vision images seen in the movie," observed Nick Davis, "which amounted to about 40 all-CG shots. All the images had to be created in the computer because Chris Nolan wanted a completely organic camera that could move anywhere, as if this is the all-seeing eye of the city. He also wanted it to have the feeling of mistakes and problems and breakup and flares; and so BUF put a lot of those subtleties into it — all in IMAX resolution."

Batman locates the Joker inside the Pruitt Building, a skyscraper under construction. Double Negative produced IMAX-resolution establishing shots of the skyscraper, based on photographs of the partially completed Chicago Trump Tower. "Trump Tower was about 600 feet tall at that point in its construction," recalled Paul Franklin, "and we took photographs of it from the top of the adjacent 1,000-foot-tall IBM Building. There was a team from Lidar VFX there, too, doing a detailed lidar survey of Trump Tower. It was slightly hairy because we had to lean over the side of this building to take our photographs, and the weather conditions were very testy. Winds were gusting at up to 70 miles an hour atop the IBM Building, making the lidar scanner vibrate furiously. It was amazing that we managed to get usable data out of it." The final digital Pruitt Building, modeled and textured by Andy Warren, was about 70 stories tall and featured volumes of intricate detail, such as cement mixers, spools of wire, cranes, shipping containers and other construction site detritus. "With all of that detail, the Pruitt Building probably had as much geometry in it as all our other models for this show put together."

In an upper story of the partially built skyscraper, the Joker holds hostages that he has snatched from Gotham's hospital and dressed in clown garb — his intention being to trick the police into taking out the hostages rather than his gang members, now dressed in patient gowns and medical personnel garb. In two digital stunt double shots, Batman leaps from the adjacent building where the police have the Joker under surveillance, glides across the abyss and enters the Pruitt Building, where he takes on the Joker and his men. Production shot Pruitt Building interiors at a 10-story structure at Cardington, used by local fire departments to practice rescue scenarios. "We dressed that up to match a building site at the Trump building," explained Nick Davis. "We put an enormous greenscreen outside the window area — about 200 feet long and 140 feet high — so that no matter what angle we shot, we could add views of Gotham beyond." Double Negative lead compositor Bronwyn Edwards and her team tracked in Gotham views comprised of matte paintings and 3D digital architecture created by CG lead Stuart Farley.

As Batman confronts the Joker, the Gotham SWAT team enters and prepares to shoot two of the hostages wearing clown masks. To save them, Batman runs and knocks them over a railing, into a stair shaft. "We did it as a stunt," stated Davis, "but it never quite worked, as the action was too dangerous to achieve practically. So we completely rebuilt the environment digitally, rebuilt the

clown characters, and used our CG Batman. We did the whole thing CG, and it is utterly seamless. It isn't a big 'wow' type of shot — but it is an amazing piece of CG.”

“It was quite a challenge,” stated Paul Franklin, “because we'd never expected to have to re-create the interior of the environment. We'd done some surveys, but we didn't have digital scans of that specific part of the set. We also didn't have digital scans of the two clown hostages that were being knocked over by Batman. To make matters worse, Chris ordered this shot only about six weeks before the final delivery on the project. Our getting it done on time was a real testament to the strength of our new pipeline. We had a comprehensive environment reprojection tool set that enabled us to digitally reproject plates onto geometry and create new camera moves after the fact.”

Batman feigns his surrender to the SWAT team — then quickly ropes them together and tosses them out the side of the building. Another late addition to Double Negative's slate of shots was an angle from a circling helicopter, looking back at the scene inside the Pruitt Building. “Chris wanted to see Batman holding his hands up, surrendering to the SWAT guys just before he knocks them out of the window,” said Franklin. “Of course, nothing had been shot for that; so that's a fully digital shot of the building exterior and the SWAT guys and Batman. Compositor Richard Reed and TD Maxx Leong added the digital doubles.”

The first roped SWAT team member falls out the high-rise window; his weight pulls the next one out — and so on, until all of them hang out the side of the building like a string of sausages. Nolan intended to shoot the stunt for real; but when the Trump Tower authorities refused permission to stage it there, the filmmakers had to set it up at another Chicago skyscraper. “We did this at the other building,” said Nick Davis, “actually roping six guys together and throwing them out the 30th floor. Then, to make it match the Trump building, Double Negative had to take that plate and do a lot of work on it.” Double Negative also did extensive cleanup on the shot, removing safety rigs and crash mats that had been affixed to the side of the building to soften the impact for the stunt performers, and carefully rotoscoping the stunt performers and the ropes dangling between them.

The movie concludes with the capture of the Joker, the death of Harvey Dent, and Batman's shouldering the blame for the demented Two-Face's killing spree. With *Batman Begins*, Christopher Nolan had delivered the grittiest Batman film ever; but he surpassed his own achievement with *The Dark Knight*, creating a setting as real as the streets of Chicago, gadgets as real as what Chris Corbould could build, and characters as real as talents such as Heath Ledger and Christian Bale could make them.

“I've read this quote in Cinefex a million times,” Nick Davis concluded, “but, more than anything else, Chris Nolan really did want to create a real world for this movie. Mostly, he did that by shooting the real world, and not relying too heavily on visual effects. He went out there on the day and shot everything he could; and then he saw where the blanks were that had to be filled by effects. It was a great way to work because we wound up with so much practical reference, all of which was grounded in real-world physics and natural dynamics — and that enabled us to create fantastic, photorealistic, similarly grounded effects.”

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Garcia, Shawn Burns, Allegra Haddigan, Emily Bowen, Aisling O'Brien, Stephanie Bruning, Danielle Morley, Gemma Samuell, Hannah Acock and Helen Arnold.

Atomic Age Hero

ARTICLE BY JOE FORDHAM

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Age Hero
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Almost three decades ago, producer George Lucas and director Steven Spielberg brokered a deal with Paramount Pictures to make *Raiders of the Lost Ark*, their ‘quick and dirty’ re-creation of 1930s movie serials, starring Harrison Ford as archeologist/adventurer Indiana Jones. The energetic film soon spawned two more Indy movies, plus a Lucasfilm TV series based on the youthful exploits of the hero — but it took nearly 13 years of development for a fourth feature to evolve.

Indiana Jones and the Kingdom of the Crystal Skull — story by George Lucas and Jeff Nathanson, screenplay by David Koepp — updated the series to the Eisenhower era, with Indiana Jones tangling with KGB Colonel Irina Spalko (Cate Blanchett) on a quest to find a crystal skull of possibly extraterrestrial origin. Jones is soon inveigled on a mission to locate a kidnapped professor, Harold Oxley (John Hurt), who holds clues to the location of the skull in South America. Accompanied by Oxley’s surrogate son, Mutt Williams (Shia LaBeouf), Jones then races Soviets to return the skull to a long-lost temple of Akator, a crucible of great power described by a 5,000-year-old legend.



Director Steven Spielberg, producer George Lucas and actor Harrison Ford spent 13 years developing their fourth collaboration, Indiana Jones and the Kingdom of the Crystal Skull. The film picked up Indy’s trail in 1957, with the archeologist/adventurer and his young accomplice, Mutt Williams (Shia LaBeouf), battling ruthless Soviet agents seeking a mysterious crystal skull in the jungles of South America. Stan Winston Studio provided skulls and special props, while visual effects supervisor Pablo Helman orchestrated action and supernatural phenomena with special effects supervisor Daniel Sudick, stunt coordinator Gary Powell, and effects crews at Industrial Light & Magic and Kerner Optical.

While assembling the production, Spielberg and producer Frank Marshall announced their intentions to maintain continuity with previous Indy movies by shooting on photochemical stock and using as many practical stunts and effects as possible. Janusz Kaminski, Spielberg's director of photography for the last 15 years, took over from Jones' former cinematographer, Douglas Slocombe, who was now in his nineties, but used some of the same anamorphic lenses employed on the first three films.



*At a secret military base in the Nevada desert, KGB Colonel Irina Spalko (Cate Blanchett) leads Indiana Jones into a vast warehouse identified only by the numeral '51' on the inside of its sliding doors. The filmmakers reprised the warehouse from the final scene of Jones' first cinematic adventure, *Raiders of the Lost Ark*, building it as a partial set inside an aircraft hangar in New Mexico, and as an additional interior set at Downey Studios in California. ILM provided digital environment enhancements, including the upper portions of the door mechanism, 3D crates, ceiling lamps and volumetric lighting effects.*

A veteran of two previous Spielberg movies, visual effects supervisor Pablo Helman joined the production and began work ten weeks before the start of principal photography, when he and ILM visual effects producer Stephanie Hornish attended a production meeting to review 3D animatics that Spielberg had developed with previsualization supervisor Daniel Gregoire and team at Halon Entertainment. "All the heads of departments took part in the meeting to decide who would do what," recalled Helman. "Dan Gregoire and his team then color-coded portions of the shots designated as practical sets, first unit, second unit and visual effects, with lens information, distances, velocities and camera speeds. It took the previz process to another level. Then the previz team remained on board through principal photography, catering to any changes during the shoot. Steven started with the previz, but in some cases he changed the shots a lot. We had to be prepared for anything."

With more than half the film's action set in South American jungles, production faced the challenge of finding virgin rainforest capable of housing complex action scenes. After considering Nicaragua, production designer Guy Hendrix Dyas found a location in Hilo, Hawaii, at the W.H. Shipman Estate, a sugar plantation and conservation area that allowed the production to cut roads for a nine-minute vehicle chase through the jungle. "Steven wanted it to look like the characters were driving through unspoiled jungle," related Stephanie Hornish, "but for safety reasons they needed a road to drive on and we had to reconstruct the jungle around it. That required a very inventive hybrid of digimatte and 3D." After shooting background plates in Hawaii, the crew shot bluescreen elements, massaged into jungle backgrounds by compositing supervisors Jay Cooper and Sean MacKenzie and their team.

Much of the action focused around the film's macguffin, the crystal skull. Stan Winston Studio created the skull as a special prop, inspired by an archeological artifact known as the Mitchell-Hedges skull — a cranium and jaw crafted from pure quartz, thought to be of pre-Columbian origins. Working from artwork based on the real crystal skull, designer Scott Patton created digital renderings in Pixologic ZBrush. "Doing the sculpture in 3D allowed us to emulate the transparent look and color of the skull quite quickly," explained Winston Studio effects supervisor John

Rosengrant. “We gave Steven a few variations. He asked us to make the eyes a bit bigger and remove the nose. We roughed in the changes in our meeting with Steven, shaping the skull on the fly.”

Rosengrant investigated possibilities for creating solid, blown-glass skulls, but the process proved too unwieldy and time-consuming. Instead, the 3D digital sculpture formed the basis for a rapid prototype reproduction of the object generated by stereo lithography. Lead mold maker Damian Fisher oversaw fabrication of props from the master object, molding, polishing, re-molding and casting translucent resin skull shapes. “We cast skulls that were almost clear,” said Rosengrant, “then added different levels of blue. Steven shot a film test with Janusz Kaminski, who shone light through the skulls and tested lighting in the eye sockets for scenes where Steven wanted to give the skull a sense of coming to life under its own power.” Skulls were cast hollow to facilitate interior lighting. To help give the skull a faceted crystal look and create a sense of depth, artists heated and deformed plastic shapes, airbrushed with shading and highlights, and inserted them into the cavity.

Principal photography began June 18, 2007, on desert locations in New Mexico, and then moved to Connecticut and Hawaii, followed by California locations and studio work in Los Angeles.

Soundstage work was conducted at Downey Studios, Sony, Warner Brothers, Paramount and Universal, where Guy Hendrix Dyas constructed an 80-foot-tall portion of a Mayan pyramid. ILM art director Christian Alzmann worked with Dyas to develop renderings of visual effects concepts, set extensions and complex effects for the film’s finale in which the power of the crystal skull is unleashed.

Secrecy surrounding the film meant that details of effects remained guarded, but the series’ legacy attracted the attentions of many effects artisans. “There was a lot of interest in being involved,” said Stephanie Hornish. “We had many phone calls and emails with people casually sending us their resumes, just in case something came up on Indy. We ended up having a very large crew, involving around 250 artists, and our digimatte department grew from ten to 22 people. It was a huge show.”

Continuing a tradition from previous Indiana Jones films, the movie begins with a match dissolve from the Paramount Pictures logo to a similar mountain on screen. In this case, a mound of dirt in the Nevada desert — out of which a prairie dog appears — provided the visual match.

Halon previsualized the scene and production shot a dirt mound in New Mexico, shaped to approximate the base of the Paramount mountain. ILM creature supervisor Eric Wong’s team then built a digital prairie dog, which animators used to produce rough animation of the creature, referencing the plate. Once Spielberg approved the performance, ILM supplied shot details to Kerner Optical. “We carved a shape in foam,” said lead model maker Nick D’Abo, who oversaw the model build for miniature supervisor Brian Gernand. “The mound was about two feet tall, and three feet in



Jones escapes Spalko’s KGB agents and takes refuge in a desert ‘Doom Town,’ built to test the effects of a nuclear bomb blast. For scenes prior to the blast, production built one house and two façades in the New Mexico desert. ILM created set extensions using digital textures of miniature houses built at Kerner Optical. For the shockwave impact, the filmmakers studied nuclear weapons test footage and determined that the most effective way to simulate the event was to build the entire town in miniature and flatten buildings practically, combining serendipitous natural forces with digital atmospheric enhancements.

diameter at the base. We made vacuforms of that, dressed it with desert dirt and rigged a blue prairie-dog-shaped mandrel to burst up through a hole, making a little shower of dirt.” ILM animation supervisor Steve Rawlins then oversaw animation of the CG rodent, adjusting the performance to timings of the crumbling dirt.

After a caption identifying the desert as Nevada, 1957, a military convoy approaches a restricted Army base, designated ‘Area 51.’ ILM digimatte supervisor Richard Bluff enhanced shots of vehicles approaching the military base, digitally extending a perimeter fence and adding distant buildings as Photoshop textures projected onto low-resolution geometry.

Spalko infiltrates the base and interrogates Indy and his associate George ‘Mac’ McHale (Ray Winstone) outside a large hangar. ILM added background buildings to plates outside a hangar set in New Mexico, and then created environment enhancements for scenes inside the hangar, where giant doors crank open. The cavernous warehouse, stacked with thousands of sealed wooden crates, was a 3D re-creation of the last shot of *Raiders of the Lost Ark* — which, in 1980, artist Michael Pangrazio had hand-rendered on glass for matte painting supervisor Alan Maley. “We have a huge reproduction of the original matte painting on one of the walls at ILM,” said Pablo Helman. “We studied that for details. The set in Downey extended just above the top of the foreground crates. We re-created everything else at ILM, including ceilings and many rows of crates.”

The hangar reveal began with a closeup of the door mechanism, rendered in 3D, and then craned back to reveal the façade of crates built on location in New Mexico. Reverse angles of characters wandering the aisles were shot at Downey Studios, with crates extending several rows back into darkness. ILM digimatte artists Barry Williams and Michael Halstead developed an automated process of 3D crate creation in ILM’s Top Hat digital asset management application. “We took photos of all the crates they had on set,” explained digital production supervisor Jeff White. “We built crates with different colored wood and stenciled markings, set them up in blocks of 200 to 300, then stacked the blocks together and lit them with volumetric lights.” ILM used 2D projections for background crates.



The blast produces blinding light energy that incinerates the exteriors of buildings, followed by a thermonuclear wind that travels horizontally across the landscape and impacts structures, causing them to shake, bend and then flatten. Kerner Optical simulated the progression of events by building an expansive 1/8-scale miniature, rigged to break apart when impacted by a series of wind effects filmed at high speed in natural sunlight. ILM then tracked the miniature plates, generated 3D fluid simulations of smoke that roiled over buildings, and integrated the miniature with digimatte desert extensions and particle work.

Jones tosses handfuls of gunpowder into the air, and airborne particles point the way to magnetized objects among the crates. ILM animated the gunpowder as a particle effect rendered with a subtle metallic sheen, designed to catch the light of overhanging lamps before quickly dissipating. The magnetic phenomenon leads Indy and the KGB to a crate that contains a sealed metal casket, tagged as an article retrieved from Roswell, New Mexico, 1947. Special effects supervisor Daniel Sudick’s team used monofilament wire-pulls to simulate the magnetic attraction of metallic objects to the casket, snapping off wire-rim spectacles and elevating Spalko’s hip-mounted sword. ILM animated other magnetized objects, elevating Soviet dog tags and metal miscellany that skitters across the floor.

Spalko slices open a metallic sarcophagus in the casket to reveal the carcass of a withered tiny being. Stan Winston Studio supplied the body, basing the design on a smaller version of the crystal skull. “We never read the script because secrecy was so tight,” said John Rosengrant, “but the little Area 51 guy, as we could understand, was some kind of alien. We scaled down the size of our crystal skull sculpture to fit the classic four-foot-tall alien frame, and then worked backwards, almost like forensic medicine. We sculpted on top of the skull in ZBrush to produce renderings of what it might look like with skin. We cast up a small skull, used that as an inner core, and sculpted onto that. Then we sculpted a body in proportion. We made it look burned, as if it had freezer damage. We also made a puppet version that could be handled like a corpse, with the skin sloughing off like a crash victim.”

Jones causes a diversion and escapes the KGB by using his bullwhip to swing from crates toward Spalko’s moving Jeep as she makes off with the alien artifact. “We first shot Harrison making his run across the crates as Spalko’s vehicle drove by left to right below,” said Pablo Helman. “The camera panned with him as he ran along crates in the ‘A’ side of the shot. We then repeated the action for the ‘B’ side, using Harrison’s stunt double. We didn’t use motion control, or do many takes. Steven planned it well with previz. He made sure the performance was correct, and then he stood back and let us do our job.”

For the B-side run and jump, Michael Justice, one of Ford’s three stunt doubles, wore a prosthetic likeness makeup created by W.M. Creations and applied by Ford’s makeup artist, Bill Corso. ILM then transitioned from Ford to the B-side of the shot as Justice passed by camera, with his face in shadow. “There was no 3D blend,” noted Jeff White.

“Compositor Jeffrey Saltzman did that all in the composite, using warping and painting to get Harrison to line up to the stunt double as he ran by camera.” Saltzman also added bullet hits of Soviet machine gun fire and removed stunt rigging. “The stunt double had safety wires at the center of his chest and his belt buckle. He grasped a bullwhip handle, which was rigged to the studio ceiling. We animated a 3D whip to latch onto a CG hanging lamp.”



Kerner Optical model maker Anna Beis attends to Doom Town mannequins outfitted in handstitched period costumes. Kerner team members also scratchbuilt 1/8-scale cars, bicycles and lawn furniture to dress the set.



Indy's escape continues in an adjacent chamber where he grapples with Colonel Dovchenko (Igor Jijikine) and accidentally activates an experimental rocket sled. Dan Sudick's team rigged a practical sled for the scene, fitted with lights inside the exhaust pipe. ILM enhanced a digital jet plume that ignites a trio of Soviet agents in its wake, using a combination of computer generated flame and a Kerner Optical pyrotechnic effect.

Sudick's team initiated sled motion and pummeled the actors with wind fans. Spielberg shot bluescreen closeups of Jones and Dovchenko reacting to the force of the rocket sled thrust. ILM then enhanced the sled motion, and generated a CG sled and rocket tunnel with lighting effects inspired by the Bay Area Regional Transit system. "I was taking the BART train over to the East Bay," recalled associate visual effects supervisor Marshall Krasser. "I noticed that as we passed lights outside, it created random flashes of colored lights. We added those to our bluescreen plates of the sled in the tunnel — a red flash here, a blue flash there — and it gave the shots a frenetic life."

The sled carries Jones and Dovchenko out into the desert, seen in a long shot beneath a nighttime sky. The production filmed the scene with a practical sled in New Mexico at dusk. ILM re-timed the sled motion, adding a jet blast and flurries of nocturnal swarming bugs. The sled decelerates by plunging into a trough of water, which absorbs its forward momentum and sends up a giant fantail of water. Kerner Optical shot the water element high speed, driving a blackscreen buck into water on the Kerner backlot. ILM composited the element with digimatte desert background and a CG rocket sled inserted into the environment.

Jones escapes into a seemingly abandoned desert town, where he finds mannequins inhabiting a 'Doom Town' built to test the effects of a nuclear bomb blast. Guy Hendrix Dyas constructed one Doom Town house and two façades as full-scale set pieces in the desert outside Deming, New Mexico. Wide shots contained enhancements by ILM and Kerner Optical. "We decided that Kerner would destroy 16 miniature buildings in a big nuclear blast," recalled Richard Bluff. "They were going to shoot this in the middle of production, and we needed to start 3D matte painting work on the environments before that, so we asked Kerner to fast-track building two houses we could use to populate the town." Kerner Optical built the model houses at 1/8-scale. ILM then photographed the miniatures from all angles, creating a library of textures in different lighting scenarios that digital artists projected as textures onto 3D structures, changing colors from house to house. Digimatte

Model makers built Doom Town homes using scaled materials and construction techniques similar to those employed in real buildings. To ensure that the structures would break apart in scale, the houses were pre-scored and lightly assembled. Aircraft cable ran inside some buildings to create initial resistance, causing walls to shimmy before disintegrating. Kerner Optical chief model maker Nick d'Abo applies final touches to the Doom Town sidewalk.



The Doom Town miniature stood on a raised platform beyond Kerner Optical's backlot slab in San Rafael. Kerner special effects supervisor Geoff Heron and his team rigged a series of air compressor tanks and pipes to feed up from below the set and blast air laterally into buildings. To match lighting in the New Mexico location photography, visual effects director of photography Marty Rosenberg referenced satellite data and online weather websites to calculate optimum time of day and wind speed. He then used four 35mm cameras and one motion-controlled Vistavision camera to capture the event in a single take.

artists then used digital photographs of 1950s toy cars projected onto CG cards to occupy streets and driveways.

Jones takes refuge in a lead-lined refrigerator as the atom bomb explodes and a shock wave obliterates the town. Kerner Optical shot closeups of full-scale mannequins incinerated by the heat wave using rubber cement, pyrotechnic gels and flash packs. In a wide shot of the town, the shock wave impacts buildings, which shimmy and break apart. "We built 22 houses at 1/8-scale," said Nick D'Abo. "They had interior and exterior detail, and used similar methods of construction as real houses, with sidings, roof tiles and roof joists. We milled 20,000 linear feet of wood as scaled-down two-by-fours, using lightweight sugar pine that had the structural integrity to keep the houses together." Model houses sat on a raised platform, 100 feet square, on the Kerner backlot slab. Kerner Optical special effects supervisor Geoff Heron flattened buildings using a series of 100-gallon air compressor tanks and an array of pipes, known as 'snoots,' that fed up through the platform behind the houses, out of view of camera. Heron's team then rigged mortars, pyrotechnic charges and hundreds of feet of primer cord, and timed detonations to suggest the shockwave crossing the suburb.

Visual effects director of photography Marty Rosenberg matched New Mexico plate photography by filming the miniature in natural sunlight, three-quarter backlit. Wind speed and time of day were crucial to the shot. Online weather websites provided atmospheric projections and satellite data of cloud coverage that allowed Rosenberg and the Kerner crew to plot a two-day window in which to shoot the miniature on a plot of land beyond the slab. In addition to previz camera setups, Rosenberg set up safety cameras, in the event of camera malfunction, to cover the one-take event. Four Arriflex 435s ran at 150 frames per second, with a motion controlled Vistavision camera on a 16-foot track that allowed a pre-programmed camera move, at six times speed, pulling back and rising above roof level as the shockwave hit.

ILM sequence supervisor John Hanson created 3D fluid simulations of smoke roiling over eaves as the shockwave tears apart buildings. Saber artists Ben O'Brien, Kevin May and Grady Cofer integrated the miniature pyro effect with digimatte desert extensions and particle work.

The shockwave carries with it a burnt and battered refrigerator, out of which tumbles Indiana Jones. Dan Sudick's team rigged a practical falling refrigerator in New Mexico, raising and lowering the full-scale appliance from a crane. To give the landing more impact, Kerner Optical filmed a refrigerator-shaped mandrel falling into miniature desert terrain, creating a puff of dirt. ILM animated a 3D refrigerator tumbling through the sky, and then impacting with the practical dust element. "The refrigerator was a combination of keyframe animation and simulation," noted Steve Rawlins. "For the last shot where it came to a stop and Indy rolled out, we ran a simulation to where it landed, then keyframed it into its last position so it matched the prop as Harrison came out."

Rattled and disoriented, Jones staggers up a berm to witness a terrifying sight as an atomic mushroom cloud rises over the desert. "It was a beautiful shot," observed Pablo Helman. "Steven framed the sun and Indy and the explosion in an iconic image. Dan Sudick provided dust and particles in the air and some fire on the ground, and we shot the plate as Harrison walked up the rise. Janusz shot right into the sun because we knew that would help us backlight the mushroom cloud; and then we dimmed the exposure of the sun through the shot."

Ben O'Brien layered the plate with the mushroom cloud, which John Hanson generated via fluid simulations and volume renders. "There was no way we could have achieved the complexity we needed in the cloud with a single 3D simulation," noted CG supervisor Craig Hammack. "It would have taken weeks to get one turnaround. Instead, we used a two-dimensional simulation as a cross-section through the cloud. We built up simulations in 50-degree increments, interpolated between those, and added a layer of noise to disguise repetitions and meld it together. We then used that as a field to dump millions of particles through the cloud." Renders of core and outer passes produced roiling clouds and interior glowing fire, combined with a subsidiary cloud ring that expanded from the cloud stem, rendered with a rain of ash and debris that ominously occluded the sky, vignetting the image around the silhouette of Jones.

Indy returns to his day job as professor of archeology at Marshall College before the KGB give chase once again. Spielberg shot establishing scenes of the college on location in New Haven, Connecticut, and on the New York Street sets at Paramount and Universal Studios. ILM digital artist Paul Huston enhanced studio settings using photographic textures that he shot in New Haven to create digimatte paintings of the spires of Jones' Ivy League college looming in backgrounds.

Indy and his new associate, Mutt, flee KGB agents to head for Cuzco, Peru, and, in a later sequence, fly deeper into the Amazon — both journeys depicted by the series' staple animated maps, which dissolve between locales with a red line tracing ports of call. "Steven wanted the animated maps to have a signature look through all the movies," remarked Pablo Helman. "Our art department very carefully matched the typeface, painting-style and color, and we simulated an optical misregistration between plates through the dissolves."

Following clues to the whereabouts of professor Oxley, Jones leads Mutt to a mountaintop Nazca Indian graveyard that contains the remains of a conquistador, Francisco de Orellana. For the entry into Orellana's tomb, W.M. Creations created skeletal remains, molded in silicone from human anatomical reference and cast in rigid polyfoam. Stan Winston Studio furnished 30 additional corpses that retained vestiges of facial properties. John Rosengrant and his team took lifecasts of Winston Studio crewmembers, cast thin latex skins from molds and then sucked the material down onto skeletal resin castings, shrinking facial details onto the bony forms. Corpses deeper in the tomb were sculpted with distorted, elongated heads, based on a pre-Columbian ritual practiced by Nazca Indians of binding children's skulls to elongate craniums.

Winston Studio also created sarcophagi cocooning the remains of Orellana and his men in material reminiscent of the Area 51 casket. When they delivered the props to set, plans changed. "Steven felt he was giving away story points too quickly," remarked Rosengrant. "We ended up doing a more traditional mummy wrap on the sarcophagi, maintaining their odd shape, but giving them a more organic finish, as if the South American people were trying to duplicate alien technology." Rosengrant's team built dummy bodies to represent a gaunt-



Indy and Mutt head into South America, flying over ancient geoglyphs in the Nazca desert in Peru. A staple of the Indiana Jones movie series, travel montages featured lingering dissolves between scenic vistas and animated

looking conquistador — who appeared to be recently dead, despite his 400-year age — and a more desiccated version. “It was a before-and-after effect. When Indy cut open the sarcophagi and the air hit the corpse, it withered before his eyes. We made 24 of those that Harrison could cut into and then peel back the sarcophagus layers like a husk.” Grady Cofer generated the transition in Saber from gaunt to shriveled corpse using digital warping, practical elements and reveal mattes.

lines tracking air miles over antique maps. ILM researched period air routes and generated animated maps based on photochemical optical montage effects in previous Indy films. The flight into Peru used footage of a biplane extracted from a liveaction plate, combined with a digimatte painting of the Nazca desert and digitally treated elements of practical polyester clouds.

Mutt discovers an open sarcophagus containing the crystal skull and a conquistador corpse, Francisco Orellana, wearing a death mask. Winston Studio created Orellana’s death mask referring to a 1951 B-movie suggested by Spielberg. “Steven wanted the mask to look South American,” said Rosengrant, “but instead of using archeological reference, he had this great idea of making it look like the face of the alien from The Man From Planet X.” Scott Patton sculpted the mask, gold-plated it with a thin coating of real gold and aged it with a green patina to create an antique look.

Spalko captures Jones and Mutt with the crystal skull and takes them to a jungle encampment where Oxley and Mutt’s mother, Indy’s former flame Marion Ravenwood (Karen Allen), are also captives. The transition to the Russian camp concludes with a camera move derived from an aerial plate shot in South America by Pablo Helman and aerial cinematographer Reed Smoot. ILM digimatte artist Brett Northcutt enhanced the plate with a digital jungle embellished with 3D trees that blended into a high angle of a studio camp set. ILM then reverse-engineered the shot from the studio plate into the aerial plate, creating a CG camera move that glided from the river, traversing treetops to reveal the Soviet campfire scene.

Mutt leads an escape attempt, but encounters a dry sand pit where Marion and Indy sink up to their chests. Dan Sudick’s team engineered the quicksand effect on an elevated set at Sony Studios. Each performer stood inside a six-foot-tall telescoping plastic tube, controlled by a hydraulic ram. The pit surrounding each tube was a foot deep, filled with Grit-o’cob — a biodegradable granular material made from ground corncobs, which displaced around the actors as they sank. Mutt pulls Marion and Indy free using the nearest available object: a giant python, triggering Jones’ pathological fear of snakes. The scene was filmed using a live 13-foot python and a pair of weighted silicone dummies created at Stan Winston Studio.

Spalko’s team makes its way through the jungle toward the lost city of Akator using an armored tree-chomping tank to clear a path through the



Mutt and Spalko duel for possession of the crystal skull while straddling an amphibious ‘duck boat’ and a Jeep hurtling through the jungle. The production filmed the jungle chase in Hawaii on a specially built road using principal performers, stunt artists, mechanical effects and members of the ILM visual effects team. Shia LaBeouf performed the vehicle-to-vehicle fight supported by a mechanical rig that extended from the back of the duck boat. ILM digitally removed safety rigging and used digital foliage and practical greenery shot at Kerner Optical to add obstacles to the vehicles’ paths and restore road surfaces to virgin rainforest.

rainforest. Special effects collaborated with the production's transportation department to provide a full-scale tree-chomper vehicle fitted with buzz saws and wood chippers for location work in Hawaii. Visual effects simulated foliage devastation.

ILM tracked tree-chomper plates and provided data to Kerner Optical, which constructed greenery on an interior stage for shots of the machine tearing into trees. "We built a mandrel representing the chomper," explained Nick D'Abo, "which didn't interact directly with the trees. We brought in palms and other plants that resembled jungle foliage. Geoff Heron devised jerk rigs and pyro to make the trees react to timings around the mandrel. We pre-cut trunks, stood them up, barely attached, on platforms against bluescreen, and then dressed vines over break points. Geoff's team placed pyro and worked out detonation timings representing chomper hits, making the trees fall."

Jungle elements included 25-foot-long tree trunks weighing up to 800 pounds aligned to production plates using a forklift truck. "Placement of the trees and how they fell was laid out in an animatic," noted Marty Rosenberg. "One of our most sophisticated shots had 15 to 20 trees that the chomper had to cut down as the camera boomed down, pulled back and panned left. We built it at 1/4-scale, which allowed us to use 12-foot trees to represent what would have been 50-foot trees. We decided to shoot it as an 'A'-side and a 'B'-side, with a transition in the middle of the pan so we wouldn't have to build a 300-degree bluescreen. The shot became so complicated we filmed each tree in a separate pass, at high speed, using a 50-foot-long track to mimic the camera move. With some repositioning in post, the trees lined up and fell where they were supposed to fall."

In a convoy following the tree-chomper, a Soviet soldier holds Jones, Marion and Mutt captive in the back of a truck. Spielberg shot principals in a truck bed gimbal set with a bluescreen backing, into which ILM composited moving jungle backgrounds. Jones then commandeers the truck and uses a shoulder-mounted rocket launcher to destroy the tree-chomper. ILM generated the tree-chomper explosion using Kerner Optical pyrotechnics combined with rigid body simulations and keyframe animation. "We added CG blades to the front of the chomper," said Steve Rawlins. "The debris and the trees being hit were practical elements and CG simulations. When Indy fired the rocket launcher, we keyframed the missile as it flew. Then we keyframed all the destruction as the chomper exploded and a cutter blade went flying and ripped off the top of Indy's truck."



At the end of the jungle chase, an army of carnivorous siafu ants swarms over KGB Colonel Douchenko (Igor Jijikine) and drags him to his doom. Spielberg shot the ant attack on the Universal Studios backlot, where stunt and special effects teams collaborated to provide interactive effects, manipulating Soviets in ant clutches. ILM generated the ants digitally using motion cycles, artificial intelligence crowd simulations and rigid body simulations. Animators generated crowds of up to 250,000 ants, match-animated digital doubles of human characters and added keyframe detail.

The explosion initiates a vehicle-to-vehicle chase where characters duel for possession of the crystal skull while dodging trees. Halon previsualized action; Spielberg then improvised on set. "Steven came up with lot of new ideas while shooting in Hawaii," Pablo Helman remarked. "We tried to cover everything by shooting HDRI passes and the standard gray ball and chrome ball lighting reference, but we couldn't do much on-set tracking because every shot was motion blurred. We

relied instead on our 3D package, Zeno, our motion tracking software and the skills of our matchmove artists, led by Jason Snell.”

First unit spent four weeks shooting the jungle chase with Helman. Then second unit continued for eight weeks with Marshall Krasser’s team, gathering backgrounds — more than half of which required digital enhancement. “The good news was that we had reference to match,” noted Krasser. “The bad news was that we had reference to match! There was only so much practical stunt work that they could do to shoot this battle moving through the jungle; and so we filmed backgrounds for those shots in Hawaii and delegated more complicated foreground action to a bluescreen shoot, five months later in L.A.”

As the chase proceeds, the KGB agents, in a Jeep, open fire on Indy and his companions in an amphibious six-wheeled ‘duck boat,’ both driving down parallel jungle roads. Spielberg filmed the scene from a camera car chasing the two vehicles without foliage separating the roads. “It was too dangerous to film greenery in the middle of the road,” explained Pablo Helman. “We shot the plate in two parts. We first established Harrison in the duck boat driving beside the Jeep at the start of the shot. We added a wall of plants that the duck boat passed behind. Then we transitioned to a second take of the duck boat reappearing with a stunt performer playing Indy as he leapt into the Jeep. We digitally replaced the stuntman’s face with Harrison’s.”

Jungle chase enhancements included Russian machine gun fire, Kerner Optical greenery and a digital library of 3D plants and digimatte paintings. “We knew that the jungle chase was going to be a major sequence,” noted Richard Bluff. “So we developed a pipeline that both technical directors and digimatte artists could use, depending on the complexity of the enhancements. Our digital model group, led by David Fogler, modeled seven different plants and trees, and we built those as a visual library in Top Hat. We could click on icons of a tree or shrub, drag it into Zeno and it would make a 3D tree. Once we hooked up lighting passes, we could render shots very quickly to see how they were working.”

Mutt finds a case of Spalko’s swords in the duck boat. The camera jibs up away from a closeup of the swords, and in one fluid motion circles Mutt and swings around to reveal a wide shot of the Jeep speeding through the jungle. The complex move was designed as a bluescreen shot, requiring a jungle background plate filmed second-unit in Hawaii. “I was starting to sweat, thinking we were never going to be able to capture the plate,” said Marshall Krasser. “I was terrified it was going to become a fully synthetic background — which would have killed us! As I was watching them rehearse with Shia, I asked second-unit director Dan Bradley if we could shoot it practically. We didn’t have the box for the swords, which was shooting first-unit, but I suggested we could build the box digitally and shoot everything else live. Dan sought Steven’s permission and Steven told us to go for it.” ILM modeled the box of swords, added digital swords on either side of a practical prop, and tracked the digital prop into the beginning of the plate, minimizing the need for digital foliage thickening the background toward the end of the shot.

For shots of Mutt engaging Spalko in a vehicle-to-vehicle sword fight, stunt drivers drove the vehicles in parallel on location while Shia LaBeouf, wearing a harness and safety line, stood anchored to the duck boat. ILM captured mobile background plates for closeups. “Our layout department came up with a rig that had a mounting for two cameras angled inwards,” Krasser

explained. “We’ve done it before with cameras angled out, but we found that created distortions and we often lost the center portion of the image between plates. By using two cameras toed in — the right camera shooting the left side of frame, and the left camera shooting the right — it gave us much better overlap and a wider field of view that allowed us to make CG camera moves in postproduction.”

To capture a low-angle shot of Mutt straddling the two vehicles, the two-camera rig filmed seven passes aimed at different quadrants of jungle, tracking backward along the jungle road. ILM’s layout department stitched together the 14-plate array to create a full motion vista of rushing vegetation. “It was a virtual reality background that we could drive our 3D camera rig through,” observed Krasser. “We could pan up and down, left and right, following the action as Mutt was getting hit in the private parts by a row of thistles.”

Janusz Kaminski shot closeups for the jungle chase at Downey Studios, surrounding cast members with a 360-degree bluescreen and using rotating jungle scrims and moving light sources to cast dappled fill light across the scene. Special effects relied on wind machines to create a sense of forward motion, while actors rode in vehicle platforms. “The vehicles had a lot of complex motion,” said Pablo Helman. “They had to move in and out and cross each other. Dan Sudick’s team did that by attaching a driver to the back of each vehicle, so each had independent motion and there were no tracks.” Sudick’s engineers mounted Jeep and duck boat chassis on platforms, with the vehicle wheels motorized to spin a few feet off the ground while platforms traversed the studio floor on casters. Each platform was capable of tilt, yaw and up/down motion, controlled via hydraulics through a 25-foot boom that extended from the rear to an electric pallet truck. An operator sat on each pallet truck using a steering wheel to control platform motion; others maneuvered pallet trucks around the studio using joystick control.

ILM blended elements into moving background plates using composite tricks to replicate lighting conditions in Hawaii plates. “We decided the interactive lighting in the jungle chase should be like driving a car down a tree-lined road,” observed Marshall Krasser, “with sunlight flashing in your face. When we added flash frames to jungle chase composites, it suddenly took the shots out of the realm of a static stage and gave them life.”

Mutt liberates the crystal skull from Spalko and passes it to Jones; but he is then separated from the group, scooped aloft by overhanging vines. LaBeouf performed the vine-raising scene on a dummy vine filmed against a bluescreen backing in Downey. ILM composited the element into a first-unit shot of the duck boat racing away into the jungle. The digimatte department then enhanced the plate with ground-level foliage, volumetric lighting and practical elements of mist drifting through light beams. Digital artists vignetted the image with foreground foliage, digital insect life and a tiny lizard.

High in the trees, Mutt encounters a troop of capuchin monkeys. LaBeouf performed with a live capuchin on a stage amid dummy vines at Downey. ILM then combined elements of LaBeouf with 60 animated capuchins and dozens of animated vines. “Once we had the layout and camera matchmoves,”



said Steve Rawlins, “animators positioned monkeys and the vines. Monkeys were keyframed, without motion cycles. As we built up animation, we started sharing elements. We would take a monkey and five vines, send it off to another animator who would rotate that to a different angle and retime it, filling up the jungle.” Eric Wong’s creature team used dynamic tentacle simulations for monkey tails and vines. Digital artists Pat Conran and Paul Sharpe oversaw fur simulations to create varieties of capuchins. Compositors added insects and lens flares to tie scenes together.

Jones and his companions escape the ants by piloting their amphibious vehicle over a cliff into a river that leads to a tier of waterfalls. Pablo Helman and aerial cinematographer Reed Smoot shot Vistavision plates for the waterfall sequence at Iguazu Falls on the border between Argentina and Brazil. ILM digimatte artists enhanced the natural beauty of the location by adding scenic waterfall elements to rocky areas. Wide shots of the duck boat cresting the falls incorporated a digital duck boat and digital doubles of Indy and company tumbling from the craft.

Meanwhile, the Jeep and duck boat clash on a narrow cliff-top road. The production shot the scene on a Hawaiian location bordering jungle beside an open field. ILM added the cliff to camera left. To provide scenic material for the view beyond the cliff, Pablo Helman oversaw a Vistavision helicopter shoot in Brazil with Reed Smoot. Digimatte artists then added plunging jungle vistas to the cliff side of the vehicle plates. “When the camera moves were minimal,” remarked Richard Bluff, “we used the photography as Pablo shot it, projected onto plains in the distance. Other times, we had to create parallax effects as the camera moved along the cliff, so we developed environments that had thousands of CG trees. Digimatte artist Yanick Dusseault did most of that work, integrating footage that Pablo shot of waterfalls and rivers into the jungle. Other artists added billowing smoke and fog to give it depth, and compositors integrated elements seamlessly into plates.”

Mutt swings in with capuchins that swarm over Spalko’s Jeep, allowing Jones’s duck boat to escape with the crystal skull. Blanchett and Soviet soldier performers mimed capuchin interactions in closeups. ILM match-animated performers and choreographed monkey cues from motions in the plate.



Indy discovers a tunnel leading to the lost city of Akator – a mythical El Dorado housed in a crater-like clearing that contains a 5,000-year-old pyramid, the resting place of untold riches. Production designer Guy Dyas constructed an 80-foot-tall portion of the temple on the backlot at Universal Studios, referencing archeological images of Mayan artifacts and structures. ILM conducted additional research, including photographic surveys of mountain temples in Peru, and then created digital environment extensions using scenic texture projections combined with production plates.

The jungle chase concludes with the duck boat crashing through a wall of foliage to land in a field, where it is almost flattened by the Soviet Jeep on a similar trajectory. Spielberg shot the double crash on the backlot at Universal Studios, panning from bushes to the duck boat in final position, rigged to emit dust as if coming to a rest. Kerner Optical shot a 1/6-scale duck boat mandrel crashing through a wall of foliage. ILM then keyframe-animated a CG duck boat to fly through frame and land in registration with the practical vehicle on set, and animated Spalko's Jeep to follow.

An army of three-inch-long, carnivorous siafu ants chases the characters to another precipice. Spielberg shot the scene on the Universal backlot, where Dan Sudick's team staged practical interactive effects to drag Soviets in ant clutches, and provided a small wire-pulled trolley to maneuver Indy's Fedora hat up an anthill. All ants were generated digitally. "We had four kinds of ants at different resolutions," related Pablo Helman. "We animated motion cycles for five different behaviors, and applied artificial intelligence crowd simulations so as ants would walk along they'd pause to 'talk' to each other and then move on, like real ants. We built a hero ant for keyframe animation, and rendered ants with light scattering and translucency to make them appear full and jelly-like."

In a low-angle shot that booms down from a wide view to an ant's-eye view of Jones and company retreating from the swarm, animators used 30 keyframe insects. "We wanted ants to fall over the lens," noted Steve Rawlins. "Steven Spielberg often mentioned that he wanted us to keep shots feeling real, and his criteria for that was, 'Could you shoot it?' So we imagined how ants would hit the camera lens and how the cameraman would react as ants were swarming over the lens."

Sequence supervisor Khatsho Orfali oversaw crowd simulations, which drove the majority of scenes. Flows of ants swarmed over 3D grids of rugged terrain, which helped to create erratic stop/start behavior and speed variations in a simulation pipeline retooled for the project. "We have previously created crowd simulations in Maya," commented Jeff White. "With the number of particles we needed in our busiest shots, we decided to port the animation to Zeno. That enabled us to generate up to 250,000 ants per shot. We combined that with rigid simulations for closeups



Scenes involving complex camera motion around the Akator pyramid required a 3D model derived from a Kerner Optical miniature built at 1/24 scale. Model makers carved the pyramid structure out of urethane foam, and then detailed it by applying scaled greenery and styrene friskets blasted with particulate material to create relief textures.



ILM digital artist Paul Huston photographs the completed pyramid miniature in natural sunlight. ILM used the resulting digital stills to build the CG structure.

where the ants stacked up, so they could collide and move on top of each other.” For interactions of ants engulfing Soviet soldiers, ILM match-animated digital doubles of the human characters to the plate and then applied the swarms.

Marion and Mutt rescue Jones and Oxley in the duck boat and steer the amphibious vehicle over a cliff where it breaks its fall on a tree. Kerner Optical shot a practical element using a 20-foot magnolia, horizontally mounted above a pool of water. Geoff Heron rigged the tree to bend as if reacting to the weight of the duck boat, dipping into the water and then whipping back. ILM integrated the tree with a full-scale duck boat, a digimatte cliff and a production plate of Soviet stunt performers tumbling from a cliff face set.

The duck boat navigates white water and plunges down a waterfall, the first of three tiered drops that culminate in a fall that destroys the craft. Spielberg shot whitewater scenes with principal performers on Falls Lake at Universal. Pablo Helman and Reed Smoot shot Vistavision scenic plates for the scene at Iguazu Falls on the border between Argentina and Brazil. “The helicopter had a 60-foot extension that allowed us to put the camera on the water,” Helman recalled. “That enabled us to get some epic shots of 300-foot-tall waterfalls looming over us.” Water-level shots of principal performers surviving the first two falls employed bluescreen shots of actors in the duck boat at Falls Lake and Iguazu footage, composited by Chad Taylor. Saber warping treatments simulated water splashes on the lens. Wide shots of the duck boat taking its final plunge included a digital duck boat and tiny digital doubles of Indy and company falling from their craft, with interactive fluid simulation enhancements.

After emerging from the river, Jones looks up at the cliff and notices a rock formation in the shape of a skull, waterfalls streaming from its eyes, signifying the entrance to the lost city of Akator. Spielberg shot the scene with performers on the Universal backlot, where Dan Sudick’s team supplied mist and wind. ILM added the portentous rock formation. “We made a digimatte painting of the skull,” stated Richard Bluff. “The Saber department pieced waterfalls into that, and then our compositing department integrated the foreground and put mist over the top.”

A tunnel beneath the falls leads Indy to the Aka-tor pyramid surrounded by mountains in a crater-like clearing, protected by Ugha warriors. Makeup department head Felicity Bowring employed W.M. Creations to create prosthetic effects for the tribesmen from designs by Miles Teves. “We sculpted more than 175 warrior prosthetics,” related W.M. Creations founder Matthew Mungle. “We made molds in silicone and duplicated those 200 times. Then we painted liquid plastic into the molds, applied Pros-Aide Bondo on top, let that dry and encapsulated that with another layer of plastic. We made more than 2,000 Ugha appliances. Felicity and hair department lead Kelvin Trahan then designed wigs and makeups and applied them to the performers.”

Spielberg filmed temple interiors on a Warner Brothers set and exteriors on the pyramid set at Universal. While the exterior set was under construction, ILM’s survey team gathered as many photographic textures, measurements and light readings as possible for potential use in wide shots of the pyramid in the valley setting. The production



then supplied animatics and extensive archeological reference to help establish the scale and look of the environment. “Guy Dyas and his team had gathered hundreds of reference images,” said Richard Bluff. “That guided our palette of textures, colors and locations. We then did our own research. We sent Paul Huston to Machu Picchu, in Peru, to photograph images of the stone temples there, with large vistas of the Andes stretching off into the distance. This was independent of the first or second unit, but we knew the essence of that environment was going to be in the film. A lot of Akator was based on that photography.”

ILM created establishing shots of the 200-foot-tall temple using digimatte and scenic texture projections combined with production plates. More complex scenes required a 3D model derived from a Kerner Optical miniature. “The pyramid miniature was 1/24-scale,” said Nick D’Abo. “It was 11 feet square and six feet tall, with a lot of miniature stone-carving done by hand. The surface had to look as if it was made up of rough blocks, which to scale were half an inch tall by three-quarters of an inch wide. To carve that, we made patterns of rocks and Mayan symbols as friskets in styrene, blasted those with ground-up walnut shells to create relief, detailed surfaces by hand and dressed it with scaled greenery.” ILM shot bracketed digital still photographs of the miniature in natural daylight and used textures to build the CG structure.

Jones and company scale the pyramid and access its interior by triggering a mechanism of sand traps and giant pivoting stone pillars. Dan Sudick’s team built the pyramid mechanism full-scale on the set at Universal. Technicians engineered four pillars, each approximately 30 feet long, with steel beams clad in foam dressed to resemble stone. Lying horizontally, the pillars radiated from the pyramid’s peak, attaching at a central pivot point to a hydraulic cylinder beneath the set. At the far end of each pillar, cables were attached to a crane above the set. When technicians lowered the hydraulic cylinder and pulled on cables, the pillars slowly rose to meet in the middle. The crane operator then lowered the upright pillar cluster down into the set, like a giant stone piston that descended into the pyramid. ILM digitally removed cables and enhanced scenic vistas around the set.

Sand released by the pillar mechanism falls away to reveal a shaft lined with precarious stone steps that retract into chamber walls. Dan Sudick’s team used Grit-o’cob to simulate sand pouring through the set and rigged a retracting staircase chamber at Sony Studios. The production constructed the set in a 30-foot-tall steel drum, dressed to resemble stone. A 360-degree spiral of movable steps protruded into the drum through slots in the walls. On the outside of the drum, steps connected to cables that fed through pulleys to a hydraulic cylinder. As the cylinder pulled cables, stairs retracted one by one into the chamber wall. Principal performers enacted up-angles wearing safety wires, with crash mats below. After a day of rehearsal, Ford and company mastered the technique of leaping from step to step.



In the temple heart of the pyramid, Jones and company watch in trepidation as Spalko returns the crystal skull to one of 13 enthroned crystal skeletons, reanimating the creature. The production built the temple heart at Sony Studios as an elaborate set filled with intricately carved and gilded Mayan architecture. Stan Winston Studio built nine crystal skeletons for the scene, working first with

Stunt doubles performed down-angles for a second day's shoot. ILM then removed safety rigging and digitally extended the set, elongating the chamber and adding further steps and the pit below.

An antechamber full of archeological artifacts leads Jones to a door sealed with an array of sliding lock mechanisms. Jones unseals the locks by bringing a crystal skull into proximity with the door. ILM enhanced the Winston Studio prop with an animated 'brain glow' effect using galaxy-like conceptual art rendered as a series of artwork layers on cards, and stacked and refracted through renders of a 3D skull. The door then snaps open — achieved with a practical rig that effects foreman Cory Faucher engineered using linear bearings and pneumatic rams rigged to slide apart with puffs of dust.

Inside the temple heart, Jones finds a cylindrical chamber made of burnished gold where 13 crystal skeletons are seated on thrones. Stan Winston Studio created nine skeletons for the scene, based on a Miles Teves design. "The sketch indicated the general feel of what Steven was looking for," commented John Rosengrant. "They were very statuesque, regal and imposing. Steven then gave us license to do whatever we needed to make that work." Working in ZBrush, Winston Studio developed a skeleton design that appeared intricate but was capable of maintaining structural integrity. "We broke the skeleton into parts and planned how we would put them together without using metal pins, which would have been visible through the translucent material." Winston artists rapid-prototyped and molded pieces, and embedded heavy-duty acrylics in resin castings to hold skeletons together. The props were assembled on set.

After Jones notices one skeleton slumped forward, its head missing, Spalko steps in to return the missing cranium to the headless creature. The scene required an editorial switch due to a disparity between props. "We made two different sizes of crystal skulls for the film," Rosengrant revealed. "There was a size that felt right for Indy to find in Orellana's tomb and to run around with in a canvas bag. But the crystal skeletons were nine feet tall and, proportionally, they needed a super-size skull. So we made two versions — one for actors to hold and another the true size to fit onto the skeletons. Steven, quite rightly, said, 'No one is going to know the difference.' We started with Cate handling the smaller size as she lifted it up, and then made the switch."

The crystal skull magnetically attaches to the spinal cord and the skeleton reanimates — an ILM digital transition from the rigid prop to an animated skeleton. The room's walls then begin to rotate and crumble, initiating the temple's collapse. "We lidar-scanned, photographed and scientifically surveyed the set," said Pablo Helman, "and, as soon as it started to move, we went to a complete digital set overseen by CG supervisor Hayden Landis. The action in the room meant that the lighting changed, so Janusz and Guy Dyas created a different lighting for the crumbling environment, backlit, with rotating lights. Christian Alzmann then used those plates to art-direct the destruction."

To tear apart masonry, ILM initiated development of a new fracture simulation tool. "We had previously used a 2D approach to creating fractures," observed Chris White. "That wasn't going to

digital models, then outputting pieces using stereo-lithography and casting parts in translucent acrylic. ILM generated the skeleton digitally for shots of the crystal entity reanimating and sitting up in its chair. The production built the temple heart at Sony Studios as an elaborate set filled with intricately carved and gilded Mayan architecture. Stan Winston Studio built nine crystal skeletons for the scene, working first with digital models, then outputting pieces using stereo-lithography and casting parts in translucent acrylic. ILM generated the skeleton digitally for shots of the crystal entity reanimating and sitting up in its chair.

work for the temple heart and the film's finale where the whole temple had to break apart in 33,000 pieces. So we developed a simulation tool that could take an object and control fracturing through fields. We could set material strengths and properties and then apply forces. We used what we called 'fracture bombs' that could define the quantity of cracks, or the pattern they spread out. For specific actions, we painted a map to describe cracking, projected that onto a surface, and cracks followed that pattern."

The digital model team duplicated temple heart stonework and gold inlays in a series of independently rotating concentric rings, then split the room into 13 wedges that could be viewed separately, or combined as floor and walls spanned past each other. "We rigid-simmed the room in pieces," explained Craig Hammack. "We passed those pieces to technical directors who did particle animations, lighting and rendering. We then baked out each piece into chunks of data and fed those back into the room for lighting. Each section got read in the memory at render time, so we couldn't interactively see texturing, but we could swap out assets or particle representations that drove each section."

A vortex opens in the ceiling, sucking debris away to an unknown destination, and Jones and his associates flee the chamber, outrunning giant stone cogs and a flood of water. To represent temple mechanisms, Dan Sudick's team engineered six-foot-diameter practical rotating gears fitted to axles and electric motors on Warner Brothers' Stage 12.

Principal performers wore safety cables that ran along a gantry above the set, flanked by bluescreens. Sudick's team flooded the set using a system of pumps to circulate water from a lower level up to a holding tank, which released water under gravity, assisted by 500-gallon air mortars that created splashes. ILM then added digital set extensions, CG rolling cogs and interactive digital water simulations.

Spalko lingers in the temple heart, which has now been denuded of its Mayan architecture to leave her stranded on a plinth at the center of a rotunda. There, she has a vision of the 13 skeletons melding to form an alien being. ILM generated the environment around Blanchett, who performed the scene surrounded by bluescreen. The alien — which production gave the code name 'Hank' — was based on a design that Christian Alzmann adapted from a



The crystal skeleton communicates telepathically with its companions and activates a mechanism that has been slumbering inside the temple for millennia. ILM generated a vapor simulation that emanated from the creatures' eyes to illustrate their reawakening power, then modeled and animated the temple heart environment for subsequent scenes of the chamber spinning and crumbling apart. / The spinning room triggers a vision in Spalko's mind as the 13 crystal skeletons coalesce into a single fully-fleshed alien being. ILM keyframe animated the creature with simulations of internal organs and interactive dynamic effects as body parts take form.



After escaping the temple, Jones and company pause on a mountaintop as Akator erupts, giving birth to a long-buried alien craft as the surrounding terrain collapses and

Winston Studio prop. "Production sent us the alien body that had been created for the scene in Area 51," said Steve Rawlins. "ILM's art department used that as a jumping-off point to create paintings, a sculpture and a CG version."

floods. Kerner Optical built a breakaway cliff face miniature using a custom formula of pyrocel and vermiculite. Cliff shapes were positioned on a platform that sat beneath two large water tanks, with metal splash panels bolted into position in front of the set. When Geoff Heron's team released trap doors in the tanks, water crashed down through the breakaway material and slammed against the panels to spectacular effect.

Spielberg proposed a transformation where skeletons appeared, in Spalko's mind, to spin past camera, propelled by the rotation of the room, then locked into place one by one to form the complete organic alien being. ILM controlled the timings of how each body came to rest, and added reactions to each impact in the arms, chest, head and innards. "We created a simulation of Hank's guts," stated Jeff White. "We built some shapes and made them jiggle as the next alien hit into him. Our first pass was pretty graphic, so we toned down simulations and blended them together."

The completed creature rises from its chair and approaches Spalko. "We initially animated a version where Hank stood up," noted Steve Rawlins, "placing his arms on the arms of the chair. But that looked too human, so I suggested to the animator to make Hank float up into the empty space between Spalko and the chair. It helped create the idea that there was something slightly unnatural about the shot, and gave it more impact."

Spalko reacts to the overload of knowledge transmitted to her from the creature, then screams and disintegrates. ILM experimented with concepts for Spalko's demise, first creating burning pyrotechnic erosions, which they then refined to a more ephemeral effect. "We used a series of fire elements that wiped upward from her feet," said Craig Hammack. "We used a fluid simulation to generate particles rising directly off her as she is sucked up into the top of the chamber, and then we ran ember particles through that simulation."

Rising water pushes Jones and his companions up through a shaft in the pyramid, out onto a neighboring mountaintop. Principal performers shot water tube scenes in a flooded set in Downey. ILM enhanced the rise through the tube with digital set extensions and water simulation. Spielberg then filmed the mountaintop on a backlot set at Universal.

From the mountaintop perch, Indiana Jones witnesses the valley floor churning and fragmenting. The Akator pyramid collapses and stones, earth and rock fragments rise in a swirling antigravity field. Amid the debris, a metallic spinning disc a quarter-mile across ascends and then vanishes. The epic shot concludes, after some 1,300 frames, with distant rock walls crumbling, rocks and debris raining down and the valley flooding.

Digital matte artist Johan Thorngren and model supervisor David Fogler collaborated on construction of the valley. Fogler's team developed models for cliffs, ground and mountains stretching off into the distance, and digimatte artists projected photo textures on top of 3D terrain. ILM generated the pyramid as a 3D simulation, comprised of 16,000 fragments, utilizing fracture tools as stones separated and then spun and rose skyward, following particle vortex fields. To break apart the valley floor, ILM applied fractures and particle enhancements. "We couldn't fracture the terrain to the enormous scale we needed," noted Craig Hammack, "so we cracked off large slabs of ground, and then added detail by emitting particles from those slabs." Zero-gravity debris rising from the plain consisted mostly of rock and terrain fragments that broke apart and crumbled, with

closeup rocks and masonry rendered to higher levels of detail. “We had temple pieces circling with dense layers of particles and instanced rock geometry onto particles at render time. There were quite a few passes of atmosphere and dust, rendered with about five different techniques and a lot of little details. We had aqueducts and houses that collapsed, trees falling over, creating a visual complexity to fill the valley half a mile across.”

ILM rendered dirt to cascade away from the polished surface of the flying saucer, and then played down the craft’s moment of departure. “The saucer was spinning super fast,” said Jeff White. “The idea was that it was driving the rotation of the valley, churning it around. But the moment where it disappeared was quite subtle — everything just stopped and fell back down.” Crashing debris fractures a cliff and unleashes a flood, realized with both digital and miniature effects. “Parts of the water in the valley were water simulations. Other parts were photographic elements of waves crashing onto rocks that we shot in San Francisco Bay. For water flooding through the cliffs, it wasn’t so much the water that we wanted to capture practically; it was the destruction and the debris — all the dirt and big chunks falling apart.”

Kerner Optical built a 1/24-scale section of breakaway mountain wall holding back a lake. The 60-foot-long cliff stood on the backlot slab beneath two 16,000-gallon water tanks perched above and behind the cliff. Geoff Heron engineered the tanks with a large trap door that would release the water in a single mighty gush. Model makers used a custom formula of pyrocel and vermiculite for breakaway portions of the cliff. Artisans cast 100 cubic yards of the compound into large rectangular blocks, which they allowed to dry and then hand carved. “We built platforms that tons of the material could sit on,” said Nick D’Abo. “Geoff Heron rigged the trap doors underneath the platforms towards the front of the set. When he dropped the water onto the platforms, chunks of the material shot straight down, out of shot, before the main force of the water burst through. We cast some areas of the cliff in solid vermiculite, so it would withstand erosion; and the less dense material would slip against it like a geological fault line.”

Dressed with greenery and mosses, the cliff walls were grouped in three sections, angled like a horseshoe, surrounded by bluescreens with two-by-eight-foot metal panels bolted into the tank to channel torrents of water. “Water, of course, is impossible to scale,” stated Marty Rosenberg. “We were plagued with that, so we applied the old magician’s idea: keep things moving, and don’t let the eye focus on anything. We positioned the camera far enough away that splashes weren’t too close to the lens.” Rosenberg shot the event — filmed late in the day, backlit — at 108 frames per second, with main and safety cameras positioned side by side.

ILM blended the miniature and digital water elements to represent the surge, followed by the calm of the flooded valley. Christian Alzmann and sequence supervisor François Lambert worked with digimatte paintings by Johan Thorngren and Yanick Dusseault to develop looks for the serenely glistening lake, surrounded by mountains and atmospheric effects. The adventure concludes with Indy, Marion, Mutt and Oxley pondering their intertwining fates. The final scene was shot on a Universal backlot set, then enhanced with South American jungle vistas.

ILM completed 557 complex visual effects shots for *Indiana Jones and the Kingdom of the Crystal Skull* — 540 of which were in the final cut, comprising 48 minutes of screen time. The project was a unique experience for ILM artists, in that they were using digital effects tools to bring back a

beloved movie hero from another filmmaking era. “People were asking, ‘How can you go digital when the old films were done practically?’” Pablo Helman said. “The reality is that if they had this technology 20 years ago, they would have used it. They used the latest in technology back then. We did the same on this film, working closely with special effects and stunt coordination to tell the story that was living in the pages of the script. Working with Steven, you always need fresh ways to create an iconic image — and you are always reminded that it’s the ideas that are important.”

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